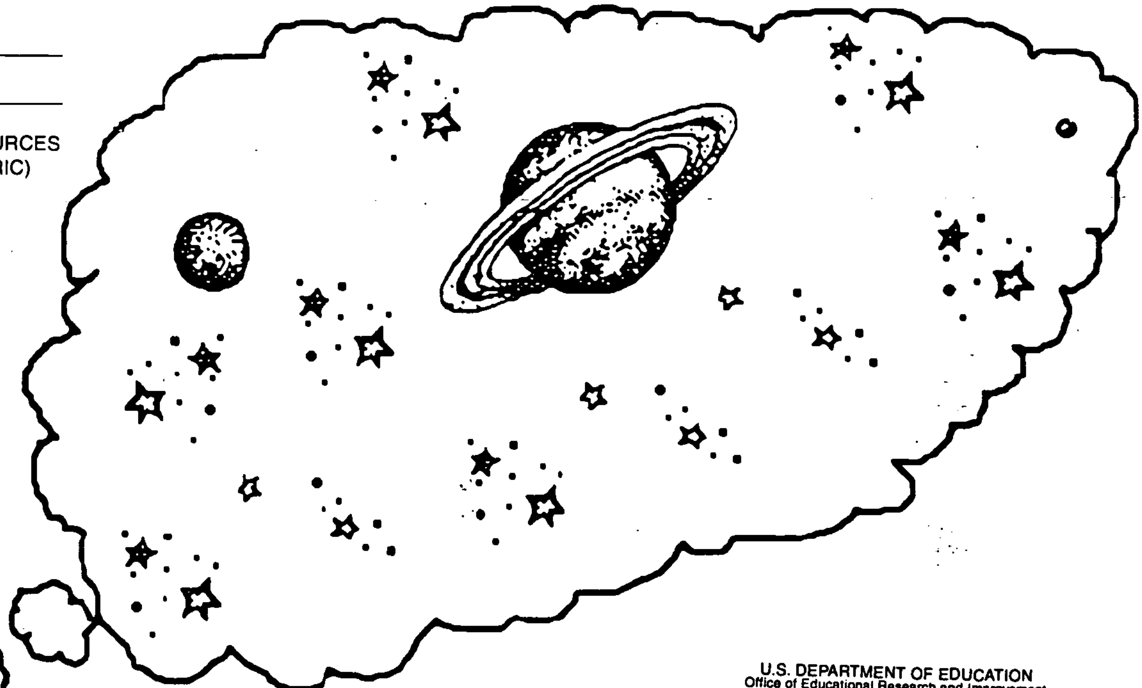
DOCUMENT RESUME

ED 406 240 SE 060 154

AUTHOR	Marble, Stephen; Fowler, Marilyn, Ed.
TITLE	Astronomy: Minds-on the Universe. Supplemental Teaching Activities for Grades K-8.
INSTITUTION	Southwest Educational Development Lab., Austin, Tex.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	Oct 93
CONTRACT	RP91002003
NOTE	148p.
AVAILABLE FROM	Southwest Educational Development Laboratory, 211 East 7th Street, Austin, TX 78701-3281.
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC06 Plus Postage.
DESCRIPTORS	*Astronomy; Elementary Education; Instructional Materials; Interdisciplinary Approach; Measurement; Misconceptions; *Science Activities; Scientific Concepts; Space Sciences; Units of Study

ABSTRACT

This teachers guide contains activities and materials created to teach astronomy concepts to children from grades K-8. It is organized into four units: (1) Earth and Stars; (2) Spheres and Orbits; (3) Stars and Gravity; and (4) Scales and Measurement. Activities are arranged within each unit around six content topics: (1) Earth; (2) Solar System; (3) Stars; (4) Motions; (5) Special Interests; and (6) Instruments. The Special Interest activities are unique activities that integrate astronomy with other areas of the curriculum or deal with special issues. Each unit contains a teacher's guide, a set of required materials, and classroom display items. The activities allow students to actively examine their prior knowledge and assumptions about astronomy and to build their conceptual understandings based on explorations and expressions of their ideas. Contains 19 references. (JRH)

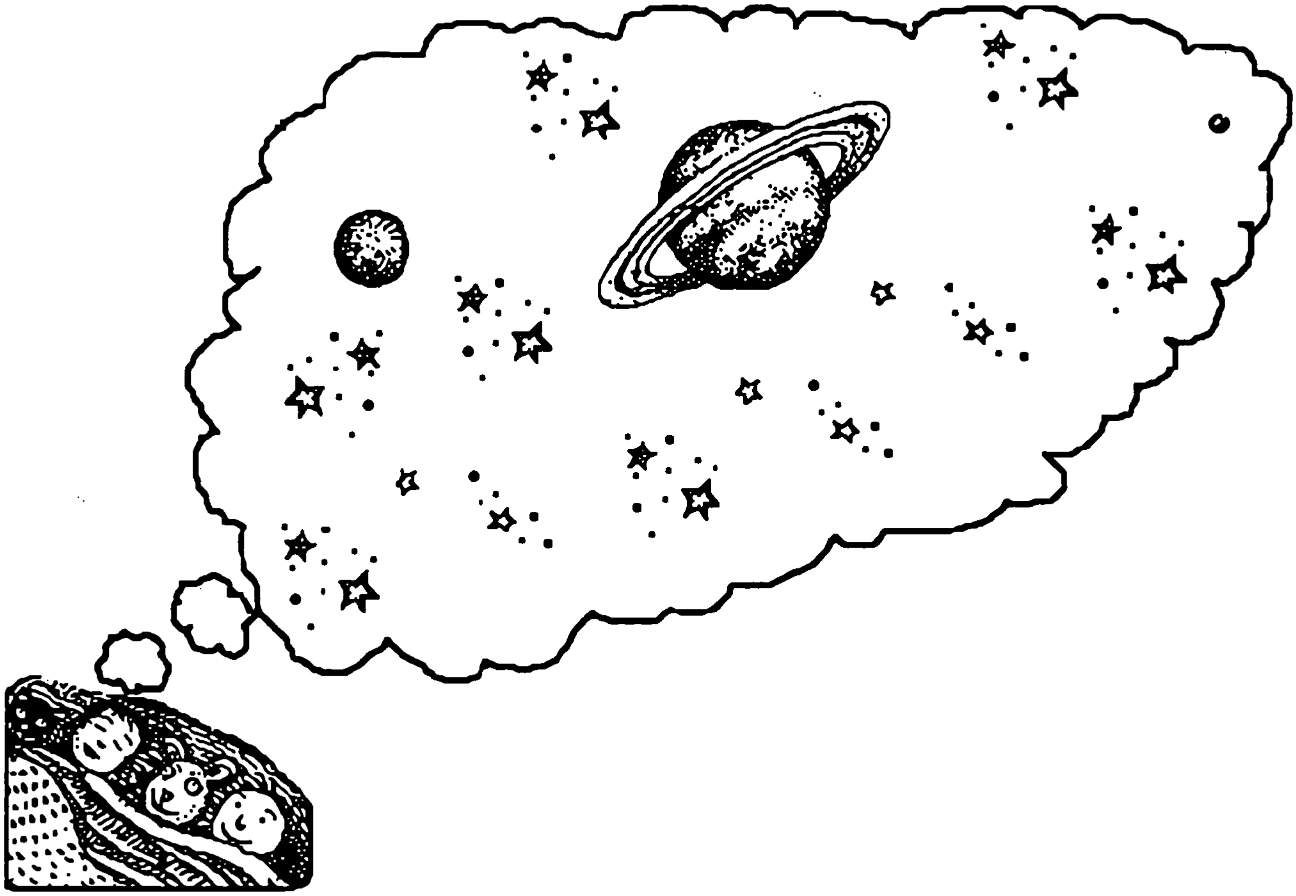


ASTRONOMY: Minds-on the Universe

Supplemental teaching activities for grades K-8

Created by Stephen Marble, Ph.D.,
Southwest Educational Development Laboratory
Austin, Texas

Edited by Marilyn Fowler, Ph.D.
Southwest Educational Development Laboratory



ASTRONOMY: Minds-on the Universe

Supplemental teaching activities for grades K-8

Created by Stephen Marble, Ph.D.,
Southwest Educational Development Laboratory
Austin, Texas

Edited by Marilyn Fowler, Ph.D.
Southwest Educational Development Laboratory

This publication and accompanying materials kit have been provided to astronomy educators for free use in the classrooms they serve with outreach efforts.

Developed through

Strengthening Science Partnerships Project

Southwest Educational Development Laboratory
211 East Seventh Street
Austin, Texas 78701-3281
(512) 476-6861

October, 1993

This publication is based on work sponsored wholly, or in part, by the Office of Educational Research and Improvement, United States Department of Education, under Contract Number RP91002003. The content of this publication does not necessarily reflect the views of OERI, the Department, or any other agency of the U.S. Government.

TABLE OF CONTENTS

ASTRONOMY
Minds-on the Universe

INTRODUCTION

Welcome to *Astronomy,* a set of activities and materials created to help you teach astronomy concepts to children from grades K-8. This teacher's guide is provided to familiarize you with an activity kit *Astronomy,* which is available to trained teachers through your local planetarium, museum, or other science resource center.

Overview

This kit has been carefully constructed to assist teachers who may have little or no astronomical experience to teach the exciting concepts of astronomy in their classes, but the activities and materials are equally appropriate for teachers who already feel comfortable teaching these ideas. The materials and activities in this kit will help make the study of the stars and planets a stimulating and rewarding learning opportunity for your students and should increase your confidence about teaching astronomy regardless of your past experience. Please read the information for teachers, as it will explain not only the procedures to follow for the activities, but the concepts they are designed to teach as well.

Acknowledgments

These activities were collected from a variety of sources, all of which are cited in the applicable lessons and/or provided in the materials kit. Most helpful in the organization and expert review of these lessons have been astronomy and science educators, including:

Dr. Mary Kay Hemenway, University of Texas at Austin
Dr. Mel Fuller, University of Arkansas at Little Rock
Dr. Marilyn Irving, Southwest Educational Development Laboratory, Austin, Texas
Dr. Quincy Spurlin, University of New Mexico in Albuquerque
Wayne Wyrick, Kirkpatrick Planetarium, Oklahoma City, Oklahoma
Gary Kratzer, Starlab Planetarium and McAuliffe Fellow, Sulphur, Louisiana
John Williams, University of Arkansas at Little Rock Planetarium
Harold Van Schaik, Garland Planetarium, Garland, Texas
Patsy Trowbridge, Alamogorda Space Center, Alamogorda, New Mexico

Museum educators in Arkansas who were crucial to development and coordination of field tests include:

Lynn Cole, Arkansas Museum of Science and History in Little Rock
Linda McDowell, MidAmerica Museum, Hot Springs, Arkansas
Ray Akers, MidAmerica Museum, Hot Springs, Arkansas
Kathy Fuhler, Arkansas Museum of Science and History in Little Rock

Thanks also go to these educators in the Crowley's Ridge, Arkansas area for pilot testing the activities in this guide Louis Midkiff, Crowley's Ridge Education Service Cooperative, Harrisburg, Arkansas :

Libby Morgan, Bytheville, Arkansas
Charlene Grtzmier, Osceola, Arkansas
Julie Wood, Osceola, Arkansas
Timothy Bingham, Memphis, Tennessee
Ruth Geeter, Memphis, Tennessee
Zuddie Waller, Memphis, Tennessee
Sheris Richardson, Wynne, Arkansas
Sandra Hollaway, Wynne, Arkansas
Vicki Slaughter, Wynne, Arkansas
Robyn Ford, Weiner, Arkansas
Martha Senteney, Weiner, Arkansas
Dianne Covington, Weiner, Arkansas
Lindy Craft, Weiner, Arkansas
Meredith Schweighart, Birdeye, Arkansas

Educators who have taken part in a field test of teacher training and used the activities in their classrooms have provided most valuable feedback and suggestions. Their creative adaptations can be found throughout the activities in this guide:

Shirley Lerz, Lake Hamilton Intermediate School, Hot Springs, Arkansas

Marcia Stacy, Lake Hamilton Intermediate School, Hot Springs, Arkansas

Janis Cook, Hot Springs Middle School, Hot Springs, Arkansas

Boo Durant, Hot Springs Middle School, Hot Springs, Arkansas

Lori Howard, Lakeside Intermediate School, Hot Springs, Arkansas

Bonnie Newnan, Lakeside Intermediate School, Hot Springs, Arkansas

Marie Cornelian, Park Elementary School, Hot Springs, Arkansas

Becky Green, Park Elementary School, Hot Springs, Arkansas

Nancy Thornton, Indian Hills Elementary School, North Little Rock, Arkansas

Dinah Allen, Indian Hills Elementary School, North Little Rock, Arkansas

Wilene Rigsby, Ridgeroad Middle School, North Little Rock, Arkansas

Jane Jackson, Ridgeroad Middle School, North Little Rock, Arkansas

Salley Massey, Montessori Cooperative School, Little Rock, Arkansas

Lia Lent, Montessori Cooperative School, Little Rock, Arkansas

Meeting teachers' needs

Astronomy has been designed with two important needs of teachers in mind.

1. Assistance in teaching unfamiliar content

Teachers, particularly elementary teachers, cannot be expected to be experts in every area that they are required to teach. Yet teachers are not excused from the task of teaching concepts with which they may only be marginally familiar. State science competencies require that students understand what stars and planets are, become familiar with the phases of the moon, grasp the role of gravity, and know the difference between rotation and revolution. This kit of materials and activities has been created to help teachers bring the basics of astronomy to their students when the time comes to look up and out.

2. Having materials on hand to teach

Teachers often cannot collect enough classroom materials in every area of science which they are required to teach. Posters, slides, and activity guides cost money, and few schools have the resources to purchase materials for activities like the ones presented here. This kit includes all of the materials the activities require for learning the concepts, plus additional classroom display items that will capture students' attention and extend their understandings.

Teaching children science

Recent findings by researchers in science education point out the important differences between what happens in classrooms where children are learning science and what happens in other classrooms. The simplest and most compelling explanation is that "good science teachers" have the support that every teacher needs. The activities and materials included in this activity kit are intended to provide that support - to assist teachers who want to do those exciting, motivating activities which will help children to learn astronomy. In order to accomplish this goal, the information researchers have collected about how children learn, what makes one activity better than another, what makes one idea more difficult than another, and what makes one lesson more powerful than another for students has been incorporated into these activities and materials. Let us look at a few of the most important findings and how they relate to these activities and materials.

1. Students' prior knowledge

It has long been thought, and most textbooks assume, that students begin a course of study with little or no information about the subject. But if you ask even the most rudimentary question of your students at the beginning of the school year, you quickly discover how oversimplified this assumption is. Most students may not have a great depth of scientific understanding, but research shows they do have firm ideas about how and why things work the way they do.

The knowledge that students bring with them to school presents a significant opportunity while at the same time introducing an extremely difficult challenge. The opportunity arises from the willingness of most students to demonstrate ideas they think they understand. The challenge of students' prior knowledge arises from the tenacity of these early ideas. Often students will adopt the learnings from school to keep the teacher happy, but continue to hold their old ideas when it comes time to use their understanding outside of the classroom. Even though adults know better, we still continue to speak of the sun setting or rising and the moon as the opposite of the sun. When challenged, adults can usually slip into a more scientific frame of mind and describe things more precisely.

Children, however, have a much more difficult time recognizing there is a scientific way of thinking about things that is different from the common everyday way. Complications can occur because some everyday words are also used in science with precise meanings. In order for children to build scientific understandings, they must have some reason to apply more specifice meanings to the words they use and to have specific applications in mind when they use those words.

2. Cooperative group activities

Like the rest of us, children learn best when they have opportunities to test their ideas in non-threatening ways. Research on learning indicates that one very useful technique that allows students to try out their ideas is the use of cooperative group activities. Group activities allow students to pool their resources, to test their ideas out on their peers, to verbalize their beliefs among equals and to challenge other interpretations without the fear of evaluative judgment by teachers. Additionally, group efforts permit students to play important roles for one another as providers of information and creators of solutions. No one advocates that teachers should use group activities exclusively, but they are appropriate and powerful when students are asked to explore new areas with which they might individually be unfamiliar.

3. Hands-on, mentally engaging activities

Research has confirmed the powerful nature of activities that allow children to manipulate concrete objects and to explore physically their mental representation. These findings have been simplified and widely discussed with the term "hands-on" and have been largely accepted. However, overuse of the term has left many educators insensitive to its importance. Hands-on activities allow children to test not only the proposed educational ideas but their own preconceived notions as well. If we dropped an object and it rose to the ceiling, our whole world would become suspect. The implications of this simple experiment illustrate the power of hands-on activities to permit children to test and re-test their ideas.

Putting it all together, the most powerful science teaching incorporates activities which start where students are, challenge their prior conceptions to cover new possibilities, permit meaningful interactions among groups of students, provide hands-on exploration of materials and ideas, and, lastly, encourage students to develop skills such as modeling, with which they can acquire more sophisticated understandings.

HOW TO USE *ASTRONOMY*

Overall organization

Astronomy is organized into four units of activities and materials. Within each unit, activities are arranged around six content topics: Earth; Solar System; Stars; Motions; Special Interests; and Instruments. The Special Interest activities in each unit are unique activities that integrate astronomy with other areas of the curriculum or deal with special issues. Each unit contains a teacher's guide, a set of required materials, and classroom display items.

The schematic presented below outlines the major concepts developed in each unit.

	Title	Earth	Solar System	Stars	Motions	Special Interests	Instruments
A	Earth and Stars	Day & Night	Sun	Constel-lations	Spin (Rotation)	Stories in the Stars	Constel-lation Models
B	Spheres and Orbits	The Spherical Earth	Planets & Moons	Modeling Constel-lations	Orbits (Revolution)	Telescopes	Lenses
C	Stars and Gravity	Which Way is Down?	Debris	Life History of a Star	Forces Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra
D	Scales & Measures	Phases and Perspectives	Planetary Scales	Is Anyone Out There?	Speed of Light	Lunar Mining	Powers of 10

Objectives

The materials and activities in each of the four units in *Astronomy* have been included to accomplish three objectives.

Objective 1: To provide teachers with activities and materials to allow them to address the state science framework requirements in astronomy for their students.

Objective 2: To permit students to actively examine their prior knowledge and assumptions about astronomy and to build their conceptual understandings based on explorations and expressions of their ideas.

Objective 3: To provide activities that focus on a few of the important ideas and relate them to one another.

Objective 1: Organizing supplemental activities for basic astronomical concepts

Astronomy is a science of inference. Not only does most school astronomy describe objects and events that occur at night, but it relates distances with numerical concepts that boggle the mind. Teaching astronomy, therefore, is a special challenge to the elementary and middle school teacher, who often must rely on text materials. These astronomy activities have been organized as a supplementary curriculum resource, providing enriched and age-appropriate activities that build understanding.

Objective 2: Providing active, engaging, conceptually sequenced experiences

This objective had two important impacts on the selection of activities and the design of the kit. The first effect is evident in the manipulative nature of these activities which challenge students to explore their own views and through group structures to cooperatively construct defensible solutions. The second impact can be seen in the sequencing of the activities, both within each unit and within each topic area. For example, the activities offered, in the unit *Earth and Stars* are conceptually less demanding than those in *Scales and Measures*, and the units in general build on the ideas in the earlier units. And within each topic area, moving from one unit to the next, the activities become progressively more abstract and less ego-centered. A good example of the relationship among the activities in similar topics of the different units can be found in the first topic area - Earth. In the first topical cell of each unit, the activities progress from Day & Night, a simple exploration of the relationship between Earth and Sky, to Phases & Perspectives, a complex manipulation of a mental model of the relationship of the Earth, the moon and the sun.

Objective 3: Focus on a few of the major ideas of Astronomy and their relationships

Current thought in science education suggests that we should teach fewer topics in greater depth and assist students in seeing the relationships among them. *Astronomy* uses activities that focus on a few major topics and build an understanding of conceptual relationships. Teachers wishing to maximize student learning can take a few minutes to read the conceptual background information provided for each unit below. This information describes the topics, their relationships, and the concepts they are designed to teach. A more detailed description of the conceptual background needed to teach the topics is provided with each unit.

Conceptual focus of the Units

The activities in this kit are designed to help teachers and students focus on the conceptual relationships among some of the big ideas in astronomy. Each unit has a number of organizing concepts that are developed through its activities. The specific background information needed to teach and understand each of these topics is described in detail in the appropriate unit.

UNIT A
The Earth and Stars

The Earth and Stars has been designed to introduce students in grades K-2 to two major conceptual strands of astronomy. The first centers on the notion of day and night and how the alternation happens. Activities include explorations of the spin of the Earth, the resulting alternation of day and night, and the sun's role in making day and night happen. The second area investigates the concept of stars and the constellation models we have built to keep their relationships to one another clear. *The Earth and Stars* unit presents models as one way to assist students in the understanding of abstract ideas, and explores the narrative models traditional American cultures developed to explain the relationships of the Earth to the stars and heavens.

UNIT B
Spheres and Orbits

Spheres and Orbits has been designed to introduce students in grades 3 and 4 to three broad concepts in astronomy: 1) the spherical shapes of the Earth and other celestial bodies and their orbital motions around the sun; 2) the influence of perspective on our view of the constellations and the stars' regular annual patterns; and 3) the basic principles of the classic instruments of astronomy: lenses and telescope.

Once students understand the three dimensional nature of the Earth, they can begin to consider its shape. Many students know it is round but do not know what a sphere is. The activities included here allow students to explore their own understandings, see models that have been historically considered, and examine evidence for the spherical Earth.

Perspective plays an important role in the shaping of our understandings. Science education researchers have shown repeatedly that students start school with many understandings based on egocentric perspectives and continue to hold these understandings unless they are challenged. One strand of activities in this box allows students to explore their perspectives, build concrete understandings of cyclical patterns of the night sky, and examine a three dimensional view of a familiar family of stars. Perspective is revisited in the fourth box in this set.

Since our knowledge is limited by our ability to collect information, tools to enhance our data collecting efforts have become very important. Lenses and telescopes have changed forever the way we think about astronomy. Students are introduced to the concepts of light collecting and magnification in the activities included in this third conceptual strand.

UNIT C
Stars and Gravity

Stars and Gravity has been designed to introduce students in grades 5 and 6 to astronomy concepts dealing with two broad themes: the attractive force of gravity and the emission of light by stars. The first broad theme challenges students to reconsider their notion of how gravity works, how it influences the orbital paths of celestial objects, and affects the births, lives and deaths of stars. The second theme focuses on the importance of light as a source of information about the age and chemical composition of stars and galaxies. The importance of solar system debris both as an influence on planetary and lunar history and as evidence for the nebular birth of stars is also considered.

UNIT D
Scales and Measures

Scales and Measures has been designed to introduce 7th and 8th grade students to astronomy concepts concerning mathematical and humanistic perspectives of the cosmos. The measure of light speed and the use of exponential powers of ten allow students to discuss the grand scale of the solar system, the galaxy and the universe, to explore the possibility of intelligent life elsewhere, and to calculate the distances to the planets and stars. The human perspective concentrates on the impact of space exploitation, the explanation for the phases of the moon, and possible approaches to take when encountering other intelligent life forms.

MATERIALS AND RESOURCES FOR TEACHING

EARTH:

What Makes Day and Night? Franklyn M. Branley

SOLAR SYSTEM:

Let's Find Out about the Sun. Martha and Charles Sharpo

MOTIONS

A Book of Planet Earth for You. Franklyn M. Branley

STARS

Beyond the Blue Horizon: Myths and legends of the Sun, Moon, Stars and Planets. Dr. E.C. Krupp.
The Search for Life in the Universe. By Donald Goldsmith and Tobias Owen

SPECIAL INTERESTS
Look to the Night Sky. Seymour Simon.
The Heavenly Zoo: Legends and Tales of the Stars. Alison Lurie
The Night Sky Book. Jamie Jobb.
The Shining Stars (Greek Legends of the Zodiac). Ghislain Vautier
The Stars: A New Way to See Them. H.A. Ray.

The Way of the Stars. (Greek Legends of the Constellations). Ghislaine Vautier.

INSTRUMENTS
Powers of Ten from The Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-2624, VHS is $39.95

Comets: Time Capsules of the Solar System from Walt Disney Educational Films, 500 South Buena Vista, Burbank, CA 91521.

Overview of the units and their activities

Each unit contains activities that are topically related. In Unit 1, for example, the topic is the Earth and the Stars. The activities are designed to introduce and familiarize students with the objects of the sky (stars, the sun, constellations) and the consequences of the Earth's spherical shape and spin (day & night). Also, each unit builds on the ideas presented in previous units while at the same time becoming more conceptually demanding.

UNIT A: THE EARTH AND STARS

Title	Earth	Solar System	Stars	Motions	Specials	Instruments
Earth and Stars	Day & Night	Sun	Constel-lations	Spin/ Rotation	Stories in the Stars	Models

EARTH: Day & Night
<u>Day and night charades</u>: Students identify important characteristics of daytime and nighttime from a deck of cards and then play charades using cards chosen by the other team.
<u>Day and night around the world</u>: Students demonstrate the sun can shine on only one half of a globe at any given time.

SOLAR SYSTEM: The Sun
<u>Where is the sun at night?</u> Students will draw two pictures depicting the Earth and the sun, one representing day-time, one representing night-time, and explore the position of the sun in each.
<u>How big is the sun?</u> Students examine the relationship between the sun and the stars and model that a closer object may appear larger.

STARS: Constellations

Star patterns: Students compare the different powers their memory brings to bear on problems when using patterns as memory aids.

MOTIONS: Spin

Sun shadows : Students see their own shadows "move" over time as the sun appears to move across the sky overhead.

Whirling and twirling: Students will imitate the spinning motion of the Earth and transfer their own experience to a model of the Earth-sun system.

SPECIAL INTEREST: Stories in the Stars

Stories on tape: Students listen to stories on the audio tape **Feather Moon: American Indian Star Tales, by Lynn Moroney.** After a brief discussion to ensure students understood the story, they will then draw a picture to illustrate the story on the tape.

INSTRUMENTS: Models

Building constellation viewers: Students will build viewers of constellations from cardboard tubes and foil.

UNIT B: SPHERES AND ORBITS

Title	Earth	Solar System	Stars	Motions	Specials	Instruments
Spheres and Orbits	The Spherical Earth	Planets & Moons	Modeling Constel-lations	Orbits/ Revolution	Telescopes	Lenses

EARTH: The Spherical Earth

How's it look? Student's clarify their personal understandings about the shape of the Earth.

Ancient models of the Earth: Students explore several historical models for the shape of the Earth.

Evidence for a sphere: Students investigate evidence the early Greeks used for their argument that the Earth is a sphere.

SOLAR SYSTEM: Planets and Moons

A cosmic vacation: Teams of students investigate characteristics of bodies of the solar system and design brochures highlighting reasons why those bodies should be considered as vacation retreats.

Crazy about craters: Students experiment with the creation of impact craters using objects and mud.

STARS: Modeling Constellations

Table top constellation: Students observe from a number of viewpoints a three dimensional model of a constellation.

MOTIONS: Orbits

What's your sign? Students will explore how the orbiting Earth sees different sets of stars in different seasons, making for the yearly cycle of the zodiac.

How old are you? Students will calculate their age on various planets.

SPECIAL INTEREST: Telescopes

Telescopes: Students examine the optical properties of telescopes using lenses and objects.

INSTRUMENTS: Lenses

Powers of magnification: Students investigate how lenses work to magnify objects.

UNIT C: STARS AND GRAVITY

Title	Earth	Solar System	Stars	Motions	Specials	Instruments
Stars and Gravity	Which Way is Down?	Debris	Life History of a Star	Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra

EARTH: Which Way is Down?

Which way is down? Students explore the properties of gravity and predict how objects at different points around the globe will fall.

SOLAR SYSTEM: Debris

The comet game: Students take a wild ride on a comet around the sun.

Collecting rocks from space: Students collect particles that may be micrometeorites from rain water.

STARS: Life History of Stars

Birth and death of a star: Students will explore the changes that occur in the lives of small mass (red dwarf), medium mass (yellow star like the sun), and very massive (blue giant) stars.

MOTIONS: Ellipses and the Planetary Mystery

The planetary mystery: The stage is set for a "mystery" involving planetary order from the sun.

Just about average: Students explore the concept of "average" by running, throwing, and spelling in different game situations.

<u>The effects of an average: what's the ninth planet?</u> Two chalk shapes are drawn on the playground to represent the orbits of Neptune and Pluto, and student "suns" observe the motion of two orbiters as they change their relative distances from the sun.

SPECIAL INTEREST: Galaxies
<u>What's your galaxy?</u>: Students develop a classification system for galaxies using photographs to illustrate galactic characteristics.

INSTRUMENTS: Colors and Spectra
<u>Light codes</u>: Students explore some of the properties of light to examine common objects and to decode a secret message.
<u>The Color in light:</u> Students use color filters and diffraction gratings to examine
the properties of light and color. They apply their learnings to posters of astronomical objects.

UNIT D: SCALES AND MEASURES

Title	Earth	Solar System	Stars	Motions	Specials	Instruments
Scales & Measures	Phases & Perspectives	Planetary Scales	Is Anyone Out There?	Speed of Light	Lunar Mining	Powers of 10

EARTH: Phases and Perspectives
<u>Earth/moon model:</u> Students explore the scale relationships between the Earth and the moon.
<u>Lunar observer</u>: Students observe the changing phases of the moon over several weeks' time to collect first hand data on lunar phases.
<u>Lunar phases:</u> Students use hand-held lunar models to observe phases of the moon.

SOLAR SYSTEM: Planetary Scales
<u>Planetary scales</u>: Students build a scale model of the solar system, calculating the relative relationships of the planets and their moons.

STARS: Is Anyone out there?
<u>Is anyone out there?</u> Students use the Drake Equation to calculate the probability of the existence of intelligent life in our galaxy.

MOTIONS: Speed of Light
Light time: Students create a light-time scale to measure the distances between the Earth, the sun and the other planets.

SPECIAL INTEREST Lunar Mining
Mining on the moon: Students role play international decision-makers while developing a proposal to clarify mining rights on the moon.

INSTRUMENTS Powers of Ten
Powers of 10: Students create a scale of the universe and locate the appropriate magnitudes for specific objects.

The Materials Kit

The kit provided contains most of the materials needed to carry out the activities in each of the units. After you use materials from your kit, it is important that you return them so that the next time the kit is used, all the necessary materials will be present. An inventory list is provided in the kit to help you check in the materials as you re-pack the kit.

Time

While you are not limited to the activities found in any one unit, you should be aware that each unit contains enough information to allow for much more than a full week of astronomy study at a conceptual level. Many of the activities suggest extensions and resources that will allow students to continue to concentrate on astronomy for several weeks, if permitted. The best strategy will be to read through the lessons and decide which activities and extensions to use in order to match the needs within your own classroom.

NOTE: Which activities to select

Your course content should guide you in the decision of which of these supplementary activities to teach. The grade level designations are intended as a rough indicator of complexity of the activities, but your own students' needs should dictate your selection.

UNIT A

UNIT A
The Earth and Stars

The Earth and Stars has been designed to introduce K - 2 students to these astronomy concepts:

- the shape of the Earth and its place in space;
- the relationship of the Earth to other celestial bodies in space;
- stars with which the Earth shares the cosmos;
- the construction and use of models as one way to assist students in the understanding of abstract ideas; and
- the narrative models that Native American cultures have developed to explain relationships among themselves, the Earth, the stars and the skies.

Introduction

Astronomy is the study of everything in the universe that is beyond the Earth's atmosphere. Most children in the early elementary grades have never considered astronomy as a formal subject. Although movies and television have broadened students' ideas about "what lies beyond the sky" or how planets might look from space, most children have thought very little about these ideas and have had few experiences that would encourage them to begin. However, children in these early grades are not without explanations for astronomical events. You can tap into their rich explanations by asking your students to answer the following questions aloud.

Why do we have day and night?
What is a star?
Where is the sun at night?
Why does the moon change shape?

While the answers students give may vary widely in their content, generally their answers will share a few attributes. Many answers will relate astronomical activities directly to the child. For example, we have day and night "so that we can go to sleep at night." Another characteristic likely to be shared by many students' answers is that they will attribute motives and purposes to inanimate heavenly bodies. The sun goes to "sleep" at night, for example, and the moon changes shape to show its moods.

In the early years of elementary school, children tend to think both concretely and egocentrically. Concrete activities allow children to explore their prior ideas, to evaluate their effectiveness, and even to formalize them in mental models and language. Giving children credit for their ideas provides them with the confidence to explore the unknown in positive ways. Through concrete, positive experiences, children develop solid bases on which to build even more sophisticated understandings.

Some concepts traditionally taught in early elementary grades, such as the astronomical reason for seasons, may be too complex for many students. Other concepts, such as day and night, stars and constellations, and the spherical shape of the Earth can be learned through experiences with models and hands-on activities. The selection of lessons in this unit offers a collection of conceptually related, high-interest, high involvement activities focused on exploring students' ideas and providing a solid foundation for astronomical studies.

Organization and sequencing

Each unit in *Astronomy* contains activities and materials centered on six topics: Earth; Solar System; Stars; Motions; Instruments; and Special Interests. Each topic develops one or more concepts and can be related to other concepts in the same unit. The concepts developed under each of these topics of *The Earth and Stars* are described below.

Title	Earth	System	Stars	Motions	Specials	Instruments
Earth and Stars	Day & Night	Sun	Constel-lations	Spin/ Rotation	Stories in the Stars	Models

The conceptual strands and the activities for each of these areas are discussed in more detail later. Reading this information will help you plan a related and focused sequence of activities for your students. In addition, several potential difficulties your students might have exploring these ideas are mentioned. You should informally discuss the concepts with your class before you begin the activities to see just where your students are in their understandings, or to look for areas of potential difficulty which we failed to mention.

Conceptual background for the activities

Earth and Stars has two basic conceptual strands:

1. the relationships among day and night, sunlight, and the spinning motion of the Earth; and
2. the observable celestial objects visible in the night sky and how cultures have invented stories and models to remember and interpret the arrangement of the stars in the sky.

1. The relationships among day and night, sunlight, and the spinning motion of the Earth

Day & Night. Almost all students will be familiar with the fact that there are two periods to every day: light and dark. Given the opportunity, students will describe many sensory differences between daylight and night, including the most important of all, the presence of sunlight during the daytime period. Asked to draw a picture of their house during the daytime, most students will automatically include a representation of the sun overhead. Yet very few students will have given much thought to the reason for these daily differences, and even fewer will be able to offer substantially correct explanations. Beginning with students familiarity with the differences between day and night, these activities challenge students to begin seeking explanations for the daily differences and offer some support for scientific concepts.

Before students can offer explanations for the light and dark periods each day they must explore the concept that every object in the presence of a lighted source has a lighted portion and a darkened portion. The lit portion faces the light source and the darkened portion is found where the mass of the object blocks the bright light and a shadow results. On cloudy days, shadows do not appear, but students can definitely distinguish cloudiness from night. This light and shadow phenomenon can be demonstrated for any and every object students can suggest. You may wish to use a globe to demonstrate that the principle holds true for round balls as well as flat objects. Looking at great art works, such as paintings by famous artists, is another way for students to explore the presence of light and shadow.

The Sun and Spin: Building on an understanding of the opposition of light and shadow, students can be challenged to explain indirectly where the sun might be found at night. Many students will have difficulty with this activity because their mental images of the Earth/sky involve an Earth below/sky above relationship. When these images, or mental models, are revised to include a curving surface and eventually a sphere for the Earth, the difficulty with placing the sun after dark becomes trivial, since it is obviously on the other side of the Earth.

But it is not enough to understand that the sun is behind the mass of the Earth to understand the regular light and dark periods we know as day and night. The regularity of these changes is the result of the Earth's spinning motion. This spinning motion can be concretely modeled for students in a number of ways. Again, although it might be helpful to use a globe and light source to demonstrate this motion, one cannot expect students to be able to make the difficult cognitive leap between what they see happening on the globe model in the classroom and what happens in the sky outside.

Students are familiar with their own shadows, and exploring how these familiar friends move during the daytime is one way to help students conceptualize the daily motion of the Earth. The regular and predictable motion of their shadows each day can stimulate and challenge students to question the obvious and search for better models. Some students will be more successful at this process than others, but the groundwork will be laid for those who have more difficulty with jumping from an egocentric, common sense-driven understanding to one based on a scientific model.

Yet a further complication to the sunlight explanation arises when we look at questions like: Why is the sky blue? and Why can we see at the same time both the stars and the sun from space but not from Earth? On Earth, we cannot see the stars during the day because of a phenomenon called light-scattering - a process by which light coming from the sun bounces off tiny particles of dust and water vapor in the atmosphere. The result is that during the daytime, light comes to our eyes from many different directions and the intensity of this light covers over, or drowns out the faint light from the distant stars and planets.

The moon, if it is in the proper position, can easily be seen in the daytime. It is, after the sun, the brightest object in the sky, so there is no real difficulty seeing it during the daytime. Light scattering does not occur in space or on the moon, since there is no dust or water vapor to bounce light around. It does occur on planets, like Venus, which have their own atmosphere. Light scattering from the many lights in large cities can be seen quite clearly and prevents us from seeing many of the fainter stars.

2. The observable celestial objects visible in the night sky and how cultures have invented stories and models to remember and interpret the arrangement of the stars in the sky

Constellations, Stories in the Sky, and Models. The second theme developed by the activities in this unit centers on the human effort to make sense of the objects in the night sky. Constellations are human inventions which arrange the stars into patterns that we can picture in our minds. Often

the individual stars are joined by imaginary lines. Nearly all cultures have their own set of stories that describe these sky pictures. The constellations commonly recognized in the northern hemisphere are based on the characters of Babylonian, Greek and Roman stories, while those of the southern night sky are based on Christian stories familiar to the sailors and world explorers during the period of European exploration. Many star names are derived from Arab astronomers who first cataloged the night sky.

The oral tradition of story telling is an important way for cultures to transmit their knowledge from one generation to the next. Before writing, story telling was the only way that information about how and why the world worked in particular ways passed from parents to children. Often, these stories allowed people to remember the order of important events or the ways animals or people interact. One particularly important sequence of events important to early agricultural peoples was the yearly coming of the Spring planting season, signaled by the appearance of certain constellations in certain locations.

Constellations and stories about the stars are cultural creations that make the world a more understandable place to live. Modern science uses many scientific strategies to explain the way the world works, but the influence of the traditional stories can still be seen in the names of the stars and constellations.

EARTH
Day & Night

Concept: The principal difference between day and night is that the sun shines during the daytime and is absent at night. This occurs because the Earth is a three-dimensional sphere. The sun's light shines on only one side of the Earth at a time, making that side "day." Living things, including people, take advantage of the regular alternation of light and dark to hunt for food or rest or hide.

Difficulties: Young children build a view of the Earth as a cosmic body based on their everyday observations. The world is a surface on which things exist and over which hangs the sky. Most children know that the sun makes daylight, but they have not thought much about where the sun might be during the night hours. Realizing that the sun can be "behind" the Earth is a central prerequisite to understanding the day/night cycle. A second important concept is that the Earth spins, allowing the sun to shine on different parts during the 24 hour day. It will be difficult to explain that the sun does not move during the day, since young children are bound up in their personal perspectives, and cannot see the world independently of their horizon.

Another difficulty might arise from students' definition of the word "day." Many use this term to mean only the period of time when the sun is shining overhead. Astronomers use the term "day" to mean one complete rotation about an axis. On Earth a day is 24 hours in length.

Relationships: The **sun** is the source of the light that makes daylight, and the **spin** of the Earth every 24 hours creates a regular cycle of periods of light and dark.

Day and night charades.

Description: Students identify important activities of daytime and nighttime as they cut out pictures from magazines, then act out the activities in teams.

Hook: Explore the concepts of light and shadows with your students. Use a bright light to demonstrate this light and shadow phenomenon for any and every object students can suggest. You may wish to use a

globe to demonstrate that the principle holds true for round balls as well as flat objects. Looking at great art works such as paintings by famous artists is another way for students to explore the presence of light and shadow.

Materials: Magazines, index cards, scissors, glue

Procedures:

NOTE: Before beginning the activity, ask the children these questions (if you haven't already done so):

Why do we have day and night?
What is a star?
Where is the sun at night?
Why does the moon change shape?

1. Make the cards for this activity or have students make their own. Students can look through scrap magazines to cut out pictures they think represent night or day or have them draw their own.
2. Divide students into two groups or have them work in smaller groups, and have each team choose a card to act out for the other team.
3. Play charades. Have students individually or in small groups act out the scenes for the entire class, and the others guess whether the activity is taking place during the day or at night. You might have children, when they have the answer, make a symbol for day or night ("day" symbol could be standing up, while a night symbol could be sitting down).

Extensions: Have students act out what animals might be doing during the day or night. Have a discussion about what kind of people work during the nighttime, for example, police officers, doctors. Students could make a mural with half of it representing things that happen during the daytime and half showing things that happen at night.

Day and night around the world.

Description: Students will see that the sun can shine on only one half of a globe at any given time.

Hook: Choose a country on the other side of the globe opposite the United States. Talk to the children about this country briefly but do not tell them that it is nighttime there. Ask them what they think kids their age are doing right "now" in that country. Accept all answers.

Materials: Globe, overhead projector, slide projector, flashlight or some other bright light, people figures and clay or tape

Procedures:

1. Select two students to place people figures onto any country on the globe, using clay or tape. Do not place the figures on the poles. Turn off the light in the room. Ask for a volunteer to position the globe in the light of the "sun" (overhead projector) in such a way that both figures are illuminated. Unless the two figures are placed exactly opposite from one another, this should be possible.
2. Have another student place a third figure on the globe on the side opposite the overhead.
3. Now challenge any student to position the globe in such a way that all three figures are illuminated. This should be difficult if not impossible. Let others try.
4. Ask them to think about why all three cannot be illuminated at one time. Some student should respond that the sphere of the Earth gets in the way or that the figure is in the Earth's shadow.
5. Discuss with students the model of the sun/Earth system that you have just been working with. The sun is the overhead; the Earth is the globe; the figures represent individual perspectives.
6. Looking at where the people figures are placed, ask the children to think about what the people in those countries are doing now; who might be waking up or eating lunch? Let some of the children turn the globe so that chosen people are in position to be waking up, going to bed, etc.
7. Ask students to stand in the light from the flashlight and, using their faces as Earth, show that they understand how to make their face "day," then turn to make it "night."

Questions:

- Is it possible for the sun to shine on both the north and south poles at the same time?

  Yes, on the first day of Spring (March 22) and first day of Fall (September 21).
- Where does the sun rise? (i.e.: In which direction does the sun rise?)

  When the sun rises, it rises in the east. For some parts of earth at certain times, the sun doesn't rise
- When the sun is its highest daily position in your town, is there daylight in India?

  When the sun is at its maximum altitude any place in the continental US (local noon) it is night in India.
- How much of the Earth is lit at one time?

1/2 of the earth is always sunlit, except when a small portion is shaded during a total solar eclipse (rare event)

Extensions: Have students choose one of the figures in another country and either write a story about what children are doing there during the daylight/night or draw pictures of their activities. Organize their stories and pictures into a Big Book and use it during reading lessons. Read to the children myths about how the day and night came into being.

Resources from the materials kit

Poster, "The Full Earth"

SOLAR SYSTEM
The Sun

Concept: The sun is a star which gives off heat and light. The sun is closer than other stars, which is why much light and heat reaches us on Earth. The sun is the biggest body of our solar system.

Difficulties: Areas of difficulty children are likely to have is that the sun is a star, it appears quite small in the sky although it is actually much larger than the Earth, and that it appears to move throughout the daylight hours. Examples of student misconceptions can be found in student drawing. One first grader drew a picture with the sun on one side of a page and the moon on the other. Another student drew rays of darkness falling from the moon.

Relationships: **Day and night** occur because the sun shines on only half of the Earth at any one time. The sun is a star very similar to many of the stars we see in the sky at night. People who look at stars at night have seen patterns called **constellations** and have given them names and invented **stories** about how they were created.

Where is my house at night?

Preparation: This activity will be more interesting if you do it on a day when the moon is in the sky during the daytime (this occurs from a few days past full phase to almost new moon). Many calendars show phases of the moon.

Description: Students will draw two pictures depicting the Earth and the sun, one representing daytime, one representing nighttime, and explore the position of the sun in each.

Hook: Ask students a series of questions: Where do they see the sun when they wake up in the morning, when they eat lunch, and when night is beginning?

Materials: Art supplies enough for two drawings per student.

Procedures:

1. Have students draw and color a picture depicting their home during the day. Somewhere in their picture they should include the sun. Mention to them that you know it is difficult to draw a flat picture of part of the round Earth.
2. Discuss student drawings briefly then ask students: "You have drawn your home in the day, but where is your home at night?" Students may reveal their impression that the sun "goes" some place during the night.
3. Have students draw a second picture. The second picture should depict their home at night. Ask students to include a drawing of the sun showing where they think it is during the night hours.
4. Have students explain their drawings and compare and discuss their pictures. Be careful not to convey the idea of "right and wrong" on any pictures, but let the students explain the representations they have shown, then have them take the drawings home and check them with the sun or moon as they have drawn them.
5. Relating this to the last activity in which students placed people figures on a globe, ask them to imagine one point on the globe is their home and ask them again, "Where does your home go at night?" Since the Earth turns, their homes go to the other side, away from the sun, at night.

Discussion: The sun "goes down" only in popular speech. It is hidden from our view by the mass of the Earth as we spin, but it continues to shine on other parts of the planet. As the Earth spins, the piece of it on which we stand faces the solar disk during the daylight and then faces away during the night hours. Students will have no difficulty drawing the sun in the day sky, but will be challenged to include a representation of the sun in their nighttime picture. This is because most young children will represent the Earth in their pictures with a straight line, put their home on the line, and the sun in the sky above. While the sun is certainly not in the sky during the night, it just as surely is not under their home; they therefore have no place to put the sun at night. More sophisticated drawings will show the Earth's surface as curved or a sphere and place the sun below the horizon during the night.

Students' pictures might include moons in the night scene. Your students might be amazed that the moon is often visible during the day but not always visible during the night. Ask them to verify this for themselves. The only nights the moon rises as the sun sets occur when the moon is full or close to it.

Extensions: Talk to the students about "nights" on other planets.

How big is the sun?

Preparation: You will need a large space like a gym or playground for this activity.

Description: Students will explore the relationship among the sun and the stars and model a larger image of the sun as an effect of distance.

Hook: Use the drawings from previous activities and have students compare the size of the stars with the size of the sun in their drawings. Then ask them: Do you think the sun is bigger or smaller than the stars we see at night? Is it possible that other stars could all be smaller than our star? Is there some way to demonstrate how a bigger star could seem smaller than the sun?

Materials: Pieces of yellow posterboard, cut into large circular disks. About 60 cm (24") in diameter.

Procedures:

1. Hold the pieces of posterboard up for students to see. Tell them that the circles are supposed to represent stars which are very big objects in our universe, bigger than our entire Earth. Explain to the children that the flat posterboard does not represent the true shape of a star, which is round like a ball. Ask the students if the pieces of posterboard look the same.
2. Give a student one of the pieces. Have the student walk half-way across the space and ask students if the pieces of paper still look the same.
3. Have this student move completely across the space and ask again if they look they same.
4. Ask students to describe how one piece of posterboard now looks different from the other. Ask them why this is so.
5. Ask students to propose a test for the explanations that they suggest. If distance is the variable, move the star circle you are holding across the same distance to see if it is now smaller as well.
6. Help students express that there is a direct relationship between distance and size - that is, the closer an object is to us, the larger it appears.
7. Ask students to tell what they think is the nearest star. Several may say that the sun is our star; and is it near or far, compared to other stars?

Extension: Talk with students about what streetlights or security lights look like from a distance and what they look like when you are standing directly under them. How is the light different? If you have a picture of a city at night taken from an airplane, show it to students and have them explain why the streetlights or other lights appear as they do. Try shining a flashlight onto the posterboard disk from near and from far. The reflected light looks much less intense or bright when the flashlight beam is far from the paper, though it covers a wider area. This can be related to the intensity of light from near and far stars and from our sun. Explain to students that stars don't shine by reflected light, but that they give off their own light.

[The relationship between distance and intensity is a square relationship, which means that for every doubling of distance (distance X 2) the intensity is reduced to 1/4 as much.]

STARS

Constellations

Concept: Stars are hot and/or glowing balls of gas that give off heat and light. Most stars are very far away, so their light is dim and we feel no heat from them. These stars look like dots in the night sky which can be connected with imaginary lines to make pictures we call constellations. Constellations make it easier to remember where certain stars are found in the night sky.

Relationships: The **sun** is also a star, but it is so close that when our side of Earth faces it, the light is very bright. We can see the other stars and constellations only at **night** because the sun's light scatters in the atmosphere during the **day**light hours, masking the light from the stars.

Difficulties: The actual images of most constellations are abstract and not at all obvious. In addition, many northern hemisphere constellations were named by the Greeks and Arabs, and the names themselves are not very helpful in remembering what they are supposed to be. The Big Dipper is only part of the constellation Ursa Major (the great bear).

☆☆☆ Star patterns ☆☆☆

Description: Students will see how much easier it is to remember a collection of dots when patterns and stories about those patterns are used as memory aids. They will create a constellation and make up a story about it.

Hook: Without talking about them, have students do a few dot-to-dot pictures. When they are finished, ask them what is in the picture and if they knew what it was going to be before they connected the dots.

Materials: Simple dot-to-dot pictures, overhead of random dot patterns, set of 3 transparencies of Leo constellation:
- #1) just the dots;
- #2) dots connected with lines;
- #3) dots and lines making Leo the lion pictures of different constellations from books, etc. (optional)

Procedure: 1. Show students the overhead #1 (from the kit) that has the dots not connected. Let them look at it for 5 seconds. Ask them to reproduce the pattern on their own papers.

2. Point out that you guess it was hard for them to repeat that pattern since it was unorganized, and didn't make sense.
3. Talk to your students about constellations. Explain that many constellations were invented to assist with the remembering star patterns that appear together in the night sky. This is a characteristic of the way humans make sense out of the world; we create patterns from the information we receive. The stories that go with them are also ways to. remember important lessons and events. Often these legends pass along ideas about how and why things happen the way they do. Some cultures find patterns that mirror patterns of landmarks on the earth. Show the students pictures of different constellations at this point.
4. Going back to the transparency with the dots (#1), tell them that it is a constellation. Give each student a copy of tranparency # 1 and tell them that they should draw what they think it might be, name it and write a story about their invented constellation. Stress that there is no right or wrong answer for this activity, that you want to see many different possibilities. Have them work individually, in small groups, or as a class.
5. Have several students share their constellations and stories with the class. When you have finished, ask them if it would be easy to remember their constellation now. Why?

<u>FOR OLDER STUDENTS:</u>

Description: Students will compare the different powers their memory brings to bear on problems using patterns as memory aids and they will see how constellations are an example of this.

Hook: Before the discussion and without students' knowledge, write a phone number on the blackboard or on overhead transparency without the spacing (e.g. 5124766861) and cover. Write down the number a second time, but reverse it and put hyphens to separate it (e.g.: 168-667-4215) Let students see the first number for five seconds and then ask them to write it down. Compare to the original. Have a show of hands to see how many correctly remembered the number. Now show the spaced and reversed number for five seconds. Have a show of hands to see what the success rate was. Ask students to account for possible differences.

Procedures: 1. Show overhead of dots of Leo constellation, transparency #1 for about 3-5 seconds. Have students attempt to memorize and reproduce the pattern of dots on their paper. Several student volunteers might share their efforts with the class.

2. Students might work in groups after their initial independent efforts to come up with a group re-creation. How closely do these match the original patterns? Are they more accurate than the independent efforts? Discuss the results with your students.
3. Show overhead of dot pattern with lines. Again show for 3 seconds and ask students to recreate the pattern individually on their paper.
4. Again, have students work in groups if there is time. This time, these groups should have much less controversy and disagreement about the placement of the stars in the pattern.
5. Ask students which overhead was easier to remember. Explore their responses by asking them why they think one was easier than the other.
6. Explain that many constellations were conceived to assist with the remembering of important information, such as times for planting crops. This is a characteristic of the way humans make sense out of the world; we create patterns from the information we receive. The stories that go with them are also ways to remember important lessons and events. Often these legends pass along ideas about how and why things happen the way they do.

Extensions: Make a big blow-up of the star pattern which the students named and wrote about. Feature one student's name and story each day and have that student read his/her story to the class. Make a gallery of their invented constellations.

A fun activity is to have one student draw the picture and then have 4-5 students make up the legend on the spot. Each one makes up a sentence about the picture and the next one continues the story with another sentence the first person always "Once upon a time..." The last person always ends with "and that is how ________ got its name."

Resources from the materials kit:
Book, The Big Dipper and You

MOTIONS
Spin

Concept: The Earth spins on its axis once every 24 hours. The Earth's axis goes from the north pole through the center of the Earth to the south pole. A widely used term for the daily spinning of the Earth or any heavenly body is rotation.

Relationships: The spin of the Earth makes **day** and **night** occur. When our side of Earth faces the sun, we call it "day." When it faces away from the sun, it is night and other stars and heavenly bodies are visible.

Difficulties: The term rotation is difficult for many students to remember. Spin is a useful substitute term to describe the motion of rotation. Children (and adults too) confuse the terms rotation and revolution. Part of the confusion children face with the terminology of rotation and revolution arises from the similarity of the spelling and sound of the words. A large portion of confusion also arises in the popular use of both words to mean the same thing, turning around.

Sun shadows

Preparation: A sunny day is needed.

Description: Students will see their own shadows "move" over time as the sun appears to move across the sky overhead.

Hook: In the light of an overhead projector make shadow puppets. Talk a bit about how shadows are produced when objects block light. Help students notice how different shapes make different shadows. The shadows we make on the ground outside are the result of our bodies blocking the light of the sun.

Materials: Sunny day. Colored chalk for drawing on sidewalk, outdoor basketball court, or driveway, or markers or dark-colored crayons and a roll of white butcher paper.

Procedures:

1. Ask students if they have noticed whether or not their shadows change during the day. Explore their answers without telling them that the purpose of this activity is to explore how their shadows change.
2. Go outside. Begin by having students experiment with making different shapes with their shadows.
3. Have students pick a spot and assume a position they will remember later in the day. Make sure they trace the outline of their shoes and put their initials inside the tracing so they will be able to find their spot and stand in just the same way when they return later. To save time with younger students, have them draw a line where their toes and heels are and have them all face the same direction - while they are working write their names for them by their footprints. Working in pairs, have one students stand on his/her spot while the partner traces the outline of the shadow. This should be done as quickly as possible. When the first shadow is finished, have the students trade places and, using a new spot, draw the outline of the second student's shadow.
4. Repeat this activity twice more during the day, with students taking the same position on the same spot. If possible, use different colors of chalk or crayons for the different tracings. A minimal time period between each tracing should be about one hour. The most dramatic differences would show if the tracings were done the first thing in the morning, just before lunch, and near the end of the school day. Save time for discussion after the last tracing.
5. Ask students what they noticed about the differences in their shadow tracings.

Discussion: Both the shape and size of students' shadows will change over the course of the day. Students should be encouraged to think about the direction and size of their shadows compared with those of other students. Some similarities might be noticed. For example, early morning shadows should be long and point to the west away from the mark where students stood. Noon shadows will be substantially shorter and point northward. The third shadow tracing will point eastward and again be longer. These regularities are the result of the direction and height of the sun above the horizon. When the sun is low in the morning sky to the east, shadows are long and toward the west. As noon approaches, the shadows will shorten and point northward (Winter noon shadows will be longer than those in early fall and late spring, since the sun is lower in the southern sky in mid-winter). As the sun nears the horizon in the

evening, the shadows will again lengthen and point toward the east and away from the setting sun.

Extensions: A model of the changing shadows can be made by sticking a toy person onto the surface of a ball. Using a bright source of light, show how the shadow moves and changes shape as the ball slowly spins.

Have students observe the shadow of a tree or a sliding board on the playground at different times during the day. Mark with numbered popsicle sticks (stick in the ground) the center of the shadow. Take the entire class out for the initial observation in the early morning (stick number one) and the final observation at the end of the day. Send pairs of students out every hour to mark the position of the shadow with the correctly numbered stick. Discuss with students how the shadow moved throughout the day.

Resources:

Whirling and twirling

Preparation: Need a gym or outdoor space.

Description: Students will imitate the spinning motion of the Earth and transfer their own experience to a model of the Earth-sun system.

Hook: Ask students to sit perfectly still. When they are, ask if they think they are perfectly still. Students will be surprised to learn that they are moving very quickly in several ways at the same time, even when they are still in relationship to their classroom and friends. The spinning velocity of the Earth at the equator is about 1000 mph! The orbital speed of the Earth around the sun is even faster. Stick a blob of clay at the equator on a globe and spin the globe. Tell them again that if the clay were a person, he or she would be spinning 1000 mph.

Materials: Any object to represent the sun in the middle of the spinning students will do. Students can be used for the sun as well. OPTIONAL: Nature Scope Astronomy Adventures, p. 22.

Procedures:

1. Select one student or some classroom object to represent the sun.
2. Have students hold hands in a circle around the "sun".
3. Students should drop hands and place one finger on the top of their head. When you give the signal, students should spin around in place. Ask them what they are doing as they spin and have them answer in chorus "spinning" or "rotating." This is a model of the rotation of the Earth.
4. When students have mastered the spinning motion, have them walk in a circle, keeping an even distance from the sun. Tell them this is "orbiting" and have them say the word as they go around in a circle. This is a rough model of the orbital motion of the Earth, its revolution.
5. Once students have had an opportunity to both spin in place and orbit the sun, have them attempt to combine the two motions. This is not an easy task, but should be fun for the students.
6. You may wish to sing the song suggested in Astronomy Adventures, set to the tune of "When Johnny Comes Marching Home." In the song, students hold hands during the orbital motions and let go for independent spinning during each verse.
7. When students have experienced both types of motion, you might ask them why they don't feel the motion of the Earth. To help them out you might ask them to think about times

they have been in motion but don't really feel it. Automobile travel is a good example. The only time the motion is noticeable is when it changes direction (around a corner) or velocity (by speeding up or slowing down). Travel in airplanes and boats and also carnival rides offer students familiar first hand experiences with high-speed travel without the sensation of moving.

Discussion: The important motion for students to be familiar with following this activity is the spinning motion of the Earth. The spinning motion of the Earth is a central concept needed to understand the repeated daily patterns of day and night. Orbital motions are dealt with in more detail in Box 2: Spheres and Orbits.

SPECIAL INTEREST
Stories in the Stars

Concept: Different cultures have invented constellations from the stars in the night sky to represent important events, stories and legends.

Difficulties: Many children today are unfamiliar with myths and legends and the role they play in the oral transmission of culture. It may be difficult for them to understand that these legends are creative devices used to remember important information by people who had no written records and were not intended to represent explanations of the natural world as created by modern western science.

Relationships: **Constellations are patterns of stars that look like dots in the night sky.** These dots are often connected with imaginary lines. In addition, nearly all cultures have some stories about the sun and the moon that explain their regular motions about the heavens.

Stories on tape

Descriptions: Students will listen to stories on the audio tape Feather Moon: American Indian Star Tales, by Lynn Moroney. After a brief discussion to see how the students understood the story, they will draw a picture to illustrate the story they heard.

Hook: Have you ever heard coyotes howling during the night? Many American Indians think of the coyote as a sneaky, lazy rascal. We will hear a story of how Coyote got into trouble for his lazy ways and lost his chance to make a constellation. Show students a picture of a coyote howling at the sky.

Materials: Audio cassette player, audio cassette Feather Moon: American Indian Star Tales, by Lynn Moroney, and **Sky Challenger** star wheels with American Indian constellations. Stick-on stars are optional.

Procedures: 1. Ask students if they have looked more closely at the night sky now that they are talking about the stars and constellations. There will be some volunteers who will be

willing to relate their experiences. Ask students if they have noticed any new constellations now that they have heard about them. After a short discussion, ask students if all the stars in the night sky fit into constellations. Why do some seem to be arranged in patterns and others do not? Explore this question for a few minutes. Then tell students that they will listen to a tape story that explains how the stars got into the sky and why some seem carefully arranged but others do not.

2. Listen to the first story, "How the Stars Came to Be" (about 9 minutes), on the audio tape **Feather Moon: American Indian Star Tales.** This story deals with the creation of the stars and their arrangement into constellations by the creatures of the Earth. If you wish to create an environment in keeping with the legend, turn off the lights.
3. Review the story with the students. Why do coyotes howl at the stars at night?
4. You may wish to talk further with students about how stories like these were used by people to explain the way the world worked. Other cultures, like the Greeks and Chinese had similar types of stories, although the constellations and characters were very different.

Extensions: Let each student choose an animal they would like to be. Tell them to draw a picture of it and place stick-on stars on points of the drawing to make it look like a constellation. Create a night sky on the wall with butcher paper and let each student place their constellation in the night sky like the animals in the story did.

Listen to other stories on this tape and have students draw pictures to illustrate them. Have students tell stories they have heard at home about constellations.

Resources from the materials kit:

Phase of the Moon Calendar
Book, **The Big Dipper and You**

INSTRUMENTS
Models

Concept: We all use models to help us think about things that might be too big, too small, or too far away to examine personally. Models can help us picture the way we think things are and lead us to ask questions about our pictures. Sometimes new models help us think about things in new ways. The zodiac is the 12 constellations that form backgrounds against which the sun, moon, and planets appear to move.

Difficulties: Many students have a difficult time remembering that models are inventions designed to help visualize ideas that are difficult to understand. Models can be so useful, however, that we forget they are not the real things, just a way of thinking about them. A dependence or strong attachment to models can cloud our thinking and prevent us from seeing important information about the ideas under consideration: they can get us "stuck." Some adults have created sustained impressions from textbook illustrations such as solar system representations that are not to scale.

Relationships: Constellations could be thought of as models that help us do several things. They help us make sense of the night sky by connecting stars with imaginary lines. They help us remember which stars are found in what part of the night sky. They help us remember important stories about people and places long past.

Building constellation viewers

Preparation: Students bring paper towel or toilet paper tubes and styrofoam meat trays that have been cleaned.

Description: Students will build viewers of constellations from cardboard tubes and foil.

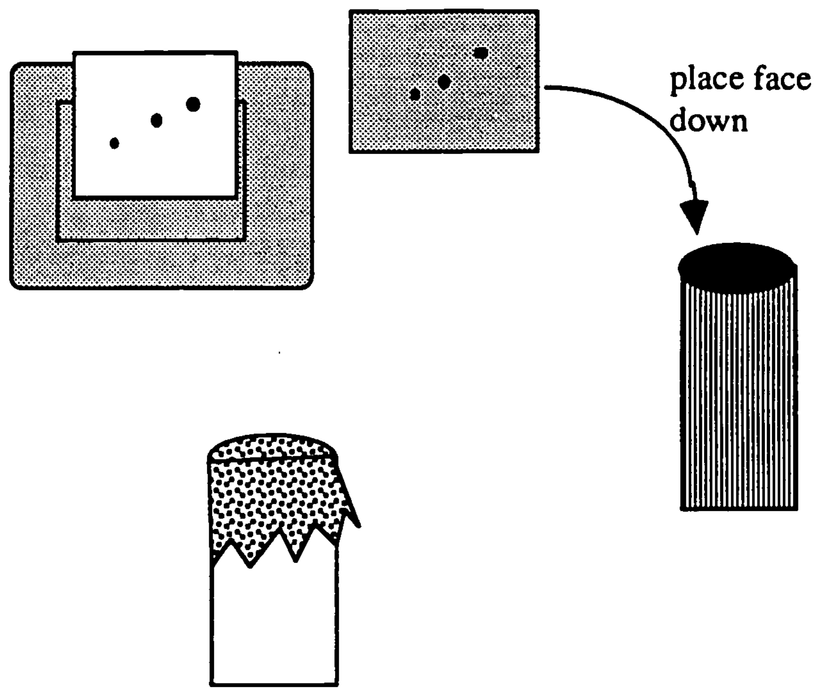
Hook: Ask students if they like to look at the stars and allow time for the students to tell stories about doing so. Share with them that throughout time, humans have been fascinated with the heavens (remind them about the legends and the naming of constellations). Tell them that humans have invented ways of producing an

artificial sky to look at the stars and the planets. These are called planetariums. They are going to make a tool to see part of the night sky.

Materials: Toilet paper cardboard roll & styrofoam meat tray (1 each per student from home), foil (provided), copies of little constellation pictures, cut apart (Copycat page, "What's Your Sign?" provided), tape, sharpened pencils

Procedures:

1. Cut foil into three inch squares and give one to each student. Since foil tears easily, have several additional squares available for students who destroy the first square. DEMONSTRATE the construction of one of these viewers to help your students understand what they are to do:
    a) Place a styro meat tray onto a desk covered with newspaper or cardboard.
    b) Place a foil square down onto the desk covering.
    c) Place a constellation picture down onto the foil.
    d) Holding the foil and picture together, punch a pencil point hole through each dot on the star picture.
    e) Remove and set aside the star picture, and pick up the foil square. It should be punched with holes at each constellation star.
    f) Checking to be sure the correct dot arrangement is facing the inside of the paper tube, wrap the foil around the end of the tube. Use tape to secure. NOTE: Show students how to check before taping, holding the foil up to the light with their paper pattern next to the foil: the dot pattern should look the same.
2. Have students choose one of the constellations from the template provided of the constellations of the zodiac and follow the procedure suggested above.
3. Have students carefully fold foil over one end of their cardboard tubes and tape the foil to the tube. Again, the foil could easily tear, so students should proceed slowly.
4. Once the foil is fixed to the end of the tube, students should write the name of the constellation on the side of the tube with marker.
5. Using a bright light source, turn off the overhead and let students look at their piece of the sky. Have students switch viewers with others who made different constellations so that they can see a variety of constellations.



Extensions: Students may wish to use other constellations than those provided on the template. The Star Challenger Wheel provided gives them a sky full to choose from.

Use cardboard oatmeal boxes to make bigger viewers.
Let students come up with their own designs for making representations of the sky and have a Planetarium Convention.

Resources from the materials kit:

Book, **The Big Dipper and You**

UNIT B

UNIT B
Spheres and Orbits

Spheres and Orbits has been designed to introduce students in grades 3 and 4 to these broad concepts in astronomy:

- the spherical shape of the Earth and other celestial bodies, planets and moons, and their orbital motions around the sun;
- the impact of perspective on our conceptions of constellations and the stars' regular annual patterns; and
- the basic principles of the classic instrument of astronomy, the telescope.

Organization and sequencing

Each unit in *Astronomy* contains activities and materials centered on six topics: Earth; Solar System; Stars; Motions; Instruments; and Special Interests. Each topic develops one or more concepts and can be related to one or more of the other concepts in the same unit. The concepts developed under each of these topics of *Spheres and Orbits* are described below.

Title	Earth	System	Stars	Motions	Specials	Instruments
Spheres and Orbits	The Spherical Earth	Planets & Moons	Modeling Constel-lations	Orbits Revolution	Telescopes	Lenses

The conceptual strands and the activities for each of these areas are discussed in detail later.

Conceptual background for the activities

Spheres and Orbits contains activities centering on three conceptual strands in Astronomy:

1. The characteristics of planets and moons, including the Earth and its moon;
2. The difference between real relationships and observed ones, particularly applied to models of constellations and the apparent annual motion of constellations in our night sky; and

3. The classic instrumentation of astronomy - lenses and telescopes.

1. The characteristics of planets and moons, including the Earth and its moon

Celestial Spheres. The Earth is one of a family of celestial bodies known collectively as the solar system. Our solar system contains the sun, the planets and their moons, and the debris (comets, asteroids, etc.) that is also in orbit around it. There are nine planets which are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. They can be divided into two basic groups: the inner, Rocky Planets which include Mercury, Venus, Earth, and Mars; and the outer, Gas Giants, which include Jupiter, Saturn, Uranus and Neptune. Pluto, the ninth planet, is unlike any other planets, and it is, until 1999, closer to the sun than Neptune.

When we see the planets in the night sky they look much like stars, but they behave very differently. This is because they are moving around the sun, shine by reflected sunlight, and they are much closer to us than the stars. The ancient peoples named the planets after the gods, and this tradition was continued for the outermost three planets even though they were discovered in modern times! The movement of the planets in the night sky is easy for us to comprehend when we remember that they are orbiting the sun. However, early peoples thought all the celestial objects orbited around the Earth. While this explained the sun and moon's apparent motions in the sky, it was extremely difficult to explain the planets' motions. A new model for the sun-centered solar system was proposed by Copernicus in the mid-1500's.

The orbital period of each planet differs depending on its distance from the sun: increasing from Mercury's speedy 88-day revolution around the sun to distant Pluto's 248- year trip around the sun. Each planet also spins on its axis, giving days of different lengths. Jupiter's day is only 10 Earth hours long, while Venus has a day that lasts 243 Earth days.

Some of the planets have moons which orbit the planet. The Earth has one moon, while Saturn has the most moons at 22. Some astronomers argue that Pluto is a moon of Neptune that escaped from an orbit around the planet and was caught in a solar orbit, becoming a planet on its own. This may explain the strange orbit of Pluto, part of which actually lies within the orbital path of Neptune, and several other odd things about this least known planet.

Planets and moons have many characteristics in common. Some planets have little or no atmospheres, like Mercury, while some large moons do have atmospheres. Some planets have dense atmospheres, like Venus and the Gas Planets, which make life there or the thought of colonization a remote possibility. Mars is the planet most like Earth and there is evidence

that at one time rivers of water flowed on the Martian surface. An atmosphere also protects the surface of a planet by providing an insulating blanket which shields out radiation and small objects. Meteoroids, small rocky bodies, are constantly entering the Earth's and other planets' atmospheres. Many burn up from friction as they meet the thick atmospheric covering. These meteors, commonly called shooting or falling stars, can be seen any night. Some do not burn up but actually crash into the surface of the planets and moons.

The cratered surface of our Moon is caused by meteors smashing into its surface; there is no atmosphere to cause the friction that would burn them up and protect the surface. Occasionally, some do survive the journey to hit the Earth's surface, just as they do on the moon. A large impact crater can be seen in Arizona. An even larger meteor impact may have been a cause for the extinction of the remaining dinosaurs 60 million years ago. The activity **Crazy Craters** explores what happens during an impact on a planet or moon. It is now thought that the Earth has had a number of serious impacts, although most of the craters have eroded. Once a meteoroid has struck the surface of a planet or moon, it is called a meteorite.

2. The difference between real relationships and observed ones, particularly applied to models of constellations and the apparent annual motion of constellations in our night sky

The view from here: We are limited in our efforts to understand the universe because we cannot easily change our perspective. If we were able to travel to other planets, stars and galaxies as easily as the Starship Enterprise does on television, our understandings would be much more sophisticated. But we are bound by our limited senses, our fixed position on Earth, and the models we can build to interpret and guide our observations. The flat Earth interpretation of the Earth's shape is adequate for daily life, getting to school and playing sports, but it becomes insufficient when we plan to travel longer distances or explain the motions of the sun, moons and planets. As our understandings become more complex, we can begin to move away from interpretations centered on our own perspective, and build more complex models which reinterpret data from external perspectives.

For some children, moving away from the egocentric perspective can be challenging and even impossible. Concrete models can help students construct and support more sophisticated understandings. While exploring new perspectives, students should be encouraged to verbalize their experiences and to listen to each other's comments. Our language reflects popular interpretations, and students can learn to listen for remarks such as "Where does the sun go at night?, or "The man in the moon...".

Several of the activities in this unit require children to challenge their perspectives and to build more sophisticated mental images based on concrete representations the students explore. The three dimensional model of the constellations that students build in the activity **Constellation Models** enables them to see how the two dimensional diagrams of constellations which we normally use offer incomplete information about the distance and relationship of stars to one another. Another activity, **What's Your Sign?**, concretely illustrates the nature of the seasonal change that we observe in the set of night sky constellations from our perspective on the Earth's surface.

3. The classic instrumentation of astronomy - lenses and telescopes

Light travels in straight lines. So, the light coming from stars and the light that is reflected from planets and moons is traveling in straight lines. Humans have found that transparent materials can be used to bend light to magnify objects. As light passes through transparent materials, like lenses, it bends; this bending of light is called refraction. Using lenses to collect light and magnify distant objects, telescopes extend the ability to see and allow us to learn about celestial spheres - the stars and the planets with their moons. This is because lenses collect more light than the human eye. The larger the lens, the greater is the amount of light that is collected. This allows fainter objects to be seen with telescopes than can be seen with the naked eye.

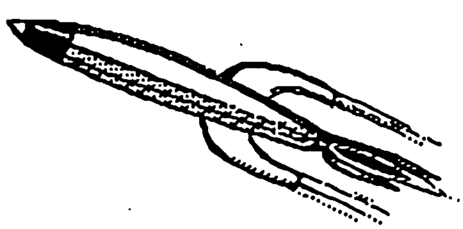
EARTH

The Spherical Earth

Concept: The Earth is a rotating sphere.

Difficulties: Common sense tells us that the Earth is flat. Even children who can point to a globe and identify it correctly as the proper shape for the Earth may not "believe" that the globe represents the Earth on which they live. One area of confusion arises in the common expression that the world is "round," which can mean many things. Another confusion can arise when children learn the Earth is not a perfect sphere, but very slightly pear-shaped.

Relationships: This theme builds on a similar one in the Earth activities of **Earth and Stars**. There, the important concept was that the Earth is a three-dimensional object so we now know that it has a side facing the sun and a side facing away from the sun. Here the important concept is that the Earth is a sphere, and its **rotation** is a smooth turning at a more or less constant rate. The **planets, moons** and even the stars all have spherical shapes, which are the result of the balancing forces of **gravity** and **rotation**.



How's it look?

Description: Students will work in teams to discuss their ideas about the shape of the Earth and then draw individual pictures to present their personal understandings.

Hook: Announce to students that today the class is going to take off and head for the stars. Have them describe the preparations needed to launch your vehicle into space and list them on the board. After several suggestions about things you will need to do, tell the kids to get ready to go.

Materials: Art materials, paper, markers, pencils, crayons.

Procedures:

1. Once you have identified several procedures for launch, you will have the class imagine going through a launch sequence together. Bunch student chairs into "shuttle crews" of four students for the first part of these procedures.
2. Have students close their eyes and visualize the entire trip. Begin with the countdown - T minus 10 and counting- 10-9-8 etc., ignition (make a roaring sound) and liftoff. Describe the roaring of the engines and the slow rising off of the ground. Tell them that they can see their school, their town or their farm, and as they get higher, land features and bodies of water and then, the United States. You might mention clouds going by. Do not mention the shape of the Earth or give any clues that might encourage students to form their models based on your description. After you have gotten them up into space, tell them that now they can see the beautiful planet Earth below them. Tell them to pay close attention and remember what it looks like so they can share with others when they return to Earth.
3. Have students open their eyes slowly and then discuss among themselves what the world looked like as it got smaller beneath them. Circulate through the room and listen to group interactions.
4. Have one member of each group pick up paper for the entire group. Have another pick up art supplies. Have students draw a picture of the Earth as they saw it from space.
5. Select student volunteers to show their pictures to the class and discuss them with the class. Put the drawings up on the bulletin board or in the hall.
6. Show students color pictures of Earth taken from space. Ask students why the Earth is called "the blue planet."

Discussion: This activity introduces two of the conceptual themes that run throughout this unit: spherical bodies and perspectives. It is open ended and can lead in many directions, depending on what students have included in their drawings. There are no "right answers" when students draw their picture models of the Earth. Some will be more sophisticated than others, but all should be positively considered and treated with respect. Allow students to explain what they have drawn, and ask them why they included certain elements. Look for unique illustrations and encourage comments from other students (positive comments should be encouraged) about how their ideas are similar or different.

One idea to look for is the degree to which students have depicted the Earth as a round shape. If students have drawn the Earth as a round shape, ask them what happens to someone standing on the bottom of the Earth. This might spark a lively debate!

From this activity, you may wish to go straight to the activity about the models ancient peoples had for the Earth; this activity comes from GEMS, Earth , Moon, and Stars. Remember that the drawings on the handout page are not the drawings of ancient peoples, but modern approximations of what the ancients are thought to have believed. After these activities, your class might be encouraged to think about how inaccurate the drawings might be given the problems of translation and changes in word meanings over time. If you wish, you could go to the activity **Which Sign Are You?** If you go this direction, the notion of the Earth as a sphere, an essential learning, will need to be considered at some later opportunity.

Extensions: Get a book that has recent color photographs of our Earth and the other planets. Look at these together and talk with the students about their similarities and differences.

Get large boxes like refrigerator boxes and have students build a pretend spaceship to travel to one of the planets which they will research. Have them write to NASA and get materials about spacecraft and space exploration.

Have a student who attended Space Camp or visited a NASA Center come and tell the class about the experience.

Ancient models of the Earth

Description: Students will explore the various historical ideas for the shape of the Earth using the activity, Ancient Models of the World in the GEMS publication Earth Moon and Stars.

Materials: Copies of student activity sheet from GEMS Earth Moon and Stars, p. 7.

Procedures: This activity is very well described in the GEMS publication Earth Moon and Stars, pages 3 - 8. Allow students time to formulate their own ideas about the path of the sun during the night. The models of the Earth that are encouraged in the GEMS activity are very free flowing and are not meant to be models of

the most scientifically correct thinking. Encourage students to be creative and to feel secure that their individual and unique thoughts have merit.

Evidence for a sphere

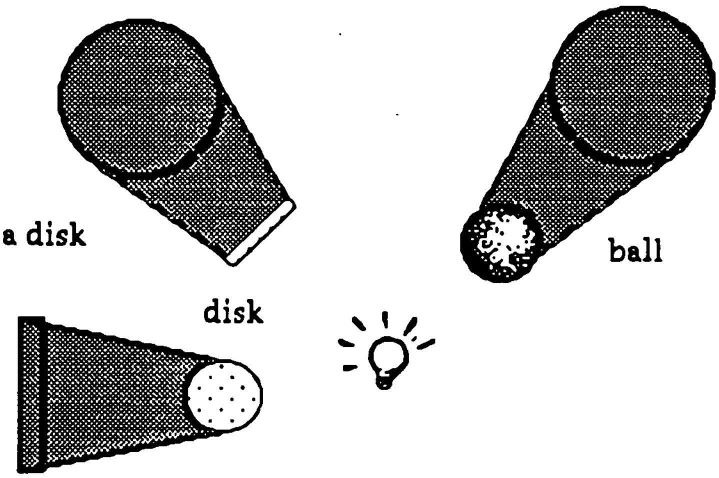
Description: This activity explores the evidence on which some early Greeks based their argument that the Earth was a sphere. This can be shown by using an overhead projector, models of a flat Earth and a spherical Earth, and the shadows they cast.

Hook: What is the shape of the Earth? How do you know? Could you prove it? How do you prove something you cannot see directly?

Materials: Overhead projector, model of a flat Earth (cardboard disk provided), model of a spherical Earth (Styrofoam ball provided)

Procedures:

1. Challenge students to describe how to prove that the world is a sphere. Give their ideas a fair hearing and be sure not to discount any student's suggestions. Ask them to think about the problems of astronomers long ago who actually solved this problem without the benefit of going into space to check it out. For example, although he was not an astronomer, Aristotle in the 4th century BC concluded that the Earth was spherical after observing an eclipse of the moon. Using good mathematical skills, Greeks calculated the dimensions of the Earth to 10% accuracy!
2. Ask students to think for a minute about where you might look for clues about whether or not the Earth is a flat disk or a sphere. One source of evidence is the shadow the Earth makes on the moon during a lunar eclipse.
3. Use the disk and the overhead projector to demonstrate that the shadow of the Earth might be either curved or straight if the Earth were shaped like a disk, depending on which direction it faces the light. This can be done by holding the disk either edge on or side on and looking at the shadow that results. Compare the disk shadows to the unchanging curved shadow of the sphere.



Discussion: The evidence used by ancients to argue for the spherical nature of the Earth is inferential evidence. Courts of law call this circumstantial evidence, rather than direct proof. Direct proof for the spherical nature of the Earth did not exist until explorers circumnavigated the planet. Students should be aware that many ideas in science are tested inferentially rather than directly, and that inferential knowledge can change depending on new developments or instruments. Some evidence, like the sun's apparent motion across the daytime sky, can be used to support a number of inferential interpretations.

Extensions: Talk about the first explorers who circumnavigated the Earth.

Resources from the materials kit:

Poster, "The Solar System"
Poster, "The Full Earth"

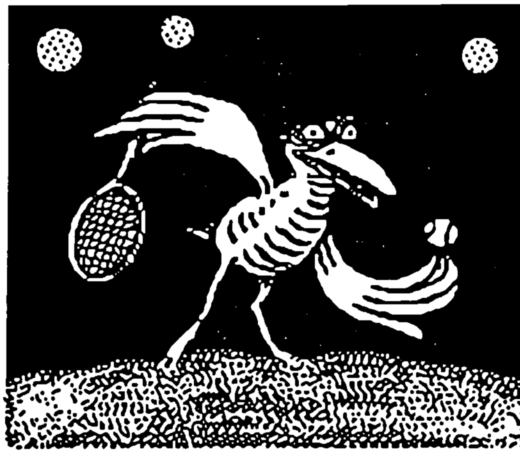
SOLAR SYSTEM

Planets and Moons

Concept: The solar system is populated with many kinds of objects. Two of the most important are the planets and their moons. Planets orbit the sun; moons orbit the planets. Some planets have no moons; Saturn has over 20. Moons and planets have some differences, but share many similarities depending on their size and composition. The four largest moons of Jupiter can be seen easily with binoculars and were discovered by Galileo with his early telescopes. The discovery that these objects moved around Jupiter and not around the Earth was a serious blow to those who believed the Earth was at the center of the solar system.

Difficulties: The planets and moons are the source of many approaches to astronomy in school text books. Comparing the planetary bodies can be beneficial, but knowing the exact number of moons each planet has around it should not be considered an important learning goal. Important characteristics to compare for the cosmic vacation activity are the density and mass, the composition (gaseous or rocky), and the lengths of the local day and year.

Relationships: In our solar system, planets and moons **orbit** bodies larger than themselves. Each of these objects is roughly **spherical** and **spins** on its axis of rotation. The moons and planets were named after the Greek and Roman gods, since unlike **constellations**, they seemed free to move about the heavens. **Telescopes** revealed that the planets had visible surfaces and that Venus had phases like Earth's moon. Only Venus and Mercury have phases, but Mercury is hard to observe since it is always near the sun. We don't see phases in the outer planets.



A cosmic vacation

Description: Pairs of students will explore the characteristics of the bodies of the solar system and design advertising materials highlighting reasons why those destinations should be considered for vacation retreats.

Hook: How many students would like to travel to the moon? Explore some of their reasons for wanting to go to such an inhospitable place. How about the planets?

Materials: Examples of real travel brochures, art materials, Planets Research Sheet (provided on following pages)

Procedures: This activity is described on page 24 of Ranger Rick's NatureScope **Astronomy Adventures**. Any travel brochures you can bring will provide a feel for the types of information students might look for in their search for reasons to travel to the far reaches of the solar system (and beyond!). Students could present their activities before they design the final travel advertisement, since hearing other students' ideas will help improve individual conceptions of what is possible.

The final products could be post cards, brochures, or travel posters for wall display.

Extensions: Make commercials for the planet using a video camera and design food products that would be used on the planet.
Have students design an amusement or a "theme" park for their planet.

Note: Some students may discover that there is no known surface for the gas giants. If they don't want to choose a floating resort, they may wish to travel to one of that planet's moons.

Planets Research Sheet

Planet ____________

Information to collect	Data:
Length of year in Earth days	
Length of day in Earth hours	
Temperature extremes (low º F to high ºF)	
Atmosphere: principal gases	
Surface gravity (x Earth gravity)	
Number of moons	

Other information of interest:

Challenge:

Design advertising materials that will entice tourists to visit your planet, giving at least 5 reasons for wanting to go there.

The advertising materials may be in any form: brochure, travel poster, postcard, TV "commercial," etc.
The reasons should be based on facts about the planet.

Crazy about craters

Preparation: Collect a bucket of dirt to use in making meteorites.

Description: Students will explore the creation of impact craters using objects and mud.

Hook: Have a sample of mud ready in an aluminum pie pan. Hold a small spoonful of mud over it and ask students to predict what will happen when you drop the mud ball into the mud in the pan.

Materials: Aluminum pie pans (provided), newspapers for cleanliness, dirt, plastic spoons and cups (one per student)

Procedures: This activity is described in Ranger Rick's NatureScope **Astronomy Adventures** on pages 27 - 29.

If you wish, substitute playdough for mud, using the recipe included below. Set the dough-craters aside to dry after the experiment.

<u>Play Dough Recipe</u>

Mix together in a bowl:
- 2 Cups flour
- 2 Tablespoons of alum

Heat to boiling:
- 1 1/2 Cup water
- 1/2 cup salt
- 1 Tablespoon vegetable oil
- a few drops any food color

Stir liquid into flour mixture. Let cool and knead. Store in airtight container.

Resources from the materials kit:

Official Rand McNally Map of the Moon
Poster, "The Solar System"
Poster, "Jupiter with Four Moons"
Poster, "Saturn with Six Moons"
Poster, "The Full Earth"

Spheres and Orbits	The Spherical Earth	Planets & Moons	Modeling Constel-lations	Orbits (Revolution)	Telescopes	Lenses

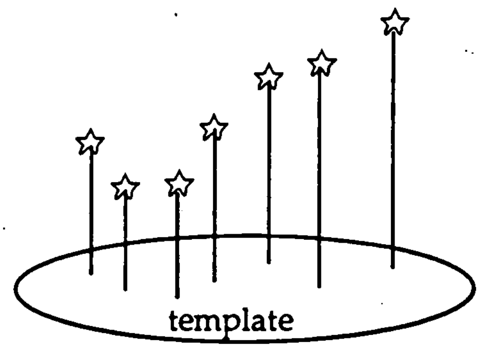
STARS
Modeling Constellations

Concept: Stars look like dots in the night sky and can be connected with imaginary lines to make pictures we call constellations. Constellations make it easier to remember positions of certain stars in the night sky. These stars are not in any way related other than that they appear in the same part of our night sky. In fact, the various stars in any one constellation may be further away from each other than they are from us! And if one of the constellations that we see from Earth were seen from another part of the cosmos, the same stars would look very unfamiliar since they would form a different pattern.

Difficulties: Imagining the great distances between stars is very difficult for children, as is seeing three dimensions in the apparent dome of the night sky. Often celestial globes reinforce the mistaken idea that all stars are located at the same distance from the Earth because they use a transparent dome which locates all the stars in one curved plane.

Relationships: Constellations appear to move across the night sky as the Earth **spins.** They also appear to change during the course of the year as the Earth **orbits** the sun; i.e. a different set of constellations is seen in the summer than are seen in the winter night skies. Yet, despite the different positions of the Earth during the course of an orbit, constellations remain recognizable, a demonstration of their tremendous distance from our vantage point. The great distances between stars make our own solar system, with its **planets and moons,** seem much like an island in a great sea of space.

Tabletop constellations



Description: Students will build a three-dimensional model of the constellation (the Big Dipper) on a table top and view it from a number of perspectives.

Materials: 7 pre-cut rods (provided), aluminum foil for stars (provided), clay for stands (provided), template for tabletop constellation (provided).

Procedures:

1. Make foil stars by rolling foil into tight balls. Tell students not to make them too tight because if the ball of foil is too tight, it will not sit on the end of the rod.
2. Place foil on tops of rods, put both into bases made of clay, and place on template. The following chart will help you identify which rod goes on which number of the template.

<u>Star Table for constellation model</u>

Star	Length of rod	Number on Template	Distance Light Years (LY)
Alkaid	22.6	1	210
Mizar	19	2	89
Alioth	18	3	68
Megrez	16.6	4	63
Phecda	15	5	90
Merak	14	6	78
Dubhe	16	7	105

3. Students should sit in a circle around the model and discuss which common constellation it seems to be. Different students will have different perspectives. They may have to raise their heads up and down to adjust the viewing angle.
4. When students think they have some idea of what the constellation is, they should draw their representation of stars and connecting lines on paper.

5. After students have completed a drawing, they should move around to see the stars from other perspectives. If they find one that seems more familiar, they should draw it.
6. If students identify the pattern as the Big Dipper, they should show other students the proper position. If students cannot identify the pattern, use the opportunity to discuss how important perspective is. Without a particular viewpoint, familiar stars fall into very unfamiliar patterns.
7. Tell the students the name of the pattern. The best perspective from which to look is from a position on a line parallel with the scale and away in the direction of 0. Star 1 will be furthest from you in this position, and the scale will be along your line of sight.
8. Take a large sheet of paper and place it behind the model and shine a flashlight at the model from the proper line of sight. The shadow of the model on the paper will clearly reveal the Big Dipper.

Extensions: Send home a note asking that a family member teach the student to recognize the Big Dipper in the night sky.
Make a drawing on the board to show how the students can use the Big Dipper to find the North Star. Use the two stars at the front of the pan/dipper bowl (from where you would pour liquid). Start at the bottom one, and follow an imaginary line through the top one. Continue until you come to the North Star. It is not very bright but it always appears in the same place in the sky. So, no matter if the dipper is right side up or upside down, you can always use it to find north. You cannot always see the entire Big Dipper.

During the time when slaves were secretly going north to escape from slavery, there was a song they sang in the fields- "Follow the Drinking Gourd" (the Big Dipper). It encouraged them to go north. Find a recording of this song and play it for your students.

In the United Kingdom, the Big Dipper is called "The Plough." What other names for that pattern can you and the children find?

Resources from the materials kit:

Book, The Big Dipper and You

MOTIONS
Orbits

Concept: The Earth orbits the sun once every year. Other planets also orbit the sun. The orbital period and velocity are determined by the distance of the orbiting body from the foci of its elliptical path. Many planets, including the Earth, have moons which orbit around them. Orbits are not perfectly circular. A widely used term for motion of any body around another is "revolution."

Difficulties: The term revolution is difficult for many students to understand, since it popularly means "a turn around." Orbit is a useful and much less confusing term for this motion. Orbiting is not the only motion of celestial bodies; they also spin. The similarity between commonly used terms for spin (rotation) and orbiting (revolution) can confuse students further.

Relationships: The orbit of the **spherical** Earth is similar to the orbits of the other **planets and moons,** as well as any other satellites. The orbital position of the Earth determines which **constellations** will be visible in the night sky.

What's your sign?

Description: Students explore how the orbiting Earth faces different sets of stars in different seasons, accounting for the yearly cycle of the zodiac.

Hook: Read this list: Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, Pisces, Aries, Taurus. Ask the students what they are. Let them answer and then tell them that they are constellations.

Materials: 12 Zodiac cards (provided)

Procedures: 1. Ask students if they know what under sign of the zodiac they were born. The discussion on pages 58-59 of Ranger Rick's Nature Scope Astronomy Adventures about how the zodiac was used in ancient times will help you answer student

questions about why the zodiac is important. Be sure to let students know that astrology is different from astronomy, and that you are interested not in predicting the future but collecting information based on observations and experiments. Astronomy is the study of the stars and the stars of the zodiac are important since the sun, moon and planets all move against the background of the 12 constellations discussed in this activity.

2. Have students volunteer to hold cards of the astronomical constellations in the zodiac. Each of 12 students should take a position in a wide circle in the following order.

   Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, Pisces, Aries, Taurus

3. One additional student volunteer is needed to play the part of the sun, or use a lamp without a shade, placed in the middle of the circle at just about eye level with the students.
4. Have the remainder of the students make a circle within, facing the zodiac constellations, with their backs to the sun. These students represent earth people looking up, and they should walk around the sun inside the circle of the constellations. As they revolve around the sun, they should look to see which constellations are visible.
5. After all the "Earth" students have revolved two or three times around the sun, have the students switch positions, so that others can see the zodiac cards.
6. Discuss with students what they have observed. They should describe the changing of the stars in their field of vision as they moved around the sun. While it may appear that the stars were moving, be sure students understand that the constellations and sun actually remained still while the Earth moved in a yearly pattern.

Extension: Find out how the position of the Big Dipper changes through the seasons.

How old are you?

Preparation: You will need student calculators for this exercise.

Description: Students will calculate their ages relative to days and years on various planets.

Hook: Ask students if they have ever heard of "dog years?" It is common to multiply the age of dogs by 7 to arrive at an equivalent age for dogs to humans. A dog that is 10 years old is considered well advanced in its life. How old would this dog be in human years? Tell students that you are interested in calculating how old they would be on different planets.

Materials: Copies of the chart provided, copies of the student worksheet, reference books for students to read about their planets.

Procedures:

1. Demonstrate for students the calculations needed to convert their Earth age to ages on other planets. An example is provided on the worksheet.
2. Let the students work in pairs to figure their ages on Mercury, Venus, and Mars. When students complete this, discuss their calculations. Make a master chart on the blackboard and fill it in for all the "ages" that you have in your class.
3. Show them how to calculate their ages on the outer planets. This could be an optional activity or you can provide them with the answers.
4. Assign each student one planet (other than Earth) and have them get into groups based on each planet.
5. Have students discuss in their groups what it would be like to live on their planet for one revolution of the sun. How would the seasons be different? How would your school year be different (on Earth we go to school about half of the year or 180 days).
6. Ask students to write one paragraph about what they would like most about living on their planet for one revolution of the sun. You may wish for them to illustrate their paragraphs for a bulletin board.

Extension: Get a reference book and read about the planet assigned to your group. Plan a birthday party for someone <u>one year old on that planet</u>. For example someone that was one year old on Jupiter would be 12 years old on Earth. What would their party be like? Challenge: Could you have a birthday cake with candles on your planet? Would the candles burn?

Resources from the materials kit:

Poster, "The Solar System"
Poster, "Jupiter with Four Moons"
Poster, "Saturn with Six Moons"
Poster, "The Full Earth"

How Old Are You?

Name________________________ Your Age in Earth Years_______

REMEMBER: A year = the number of days that it takes a planet to make one orbit around the sun. For example:

one year on Earth = 365 days
it takes 365 days for Earth to make one orbit.

1. First you need to find out how old are you in **days** on Earth:
   a) Multiply your age by 365:
   _____ X 365 = _____(your age in days on Earth)

2. Here's a sample calculation for your age in years on an imaginary planet, Clintonia, which takes 730 days to orbit the sun:

   Your **age in days on Earth** divided by 730 days (1 year on Clintonia) = Your approximate age on Clintonia.

Calculate now:
age in days on Earth ÷ 730 days = ________ (your age in years on Clintonia)

3. Calculate your age on Mercury, Venus and Mars. Use your calculator.

Planet	**Orbital Period**	**My age in local years**
Mercury	88 days	______
Venus	225 days	______
Mars	687 days	______

*4. Some planets take so long to make one orbit, we use years instead of days to talk about them. If you are 9 years on Earth, you would be about one-third of a year old on Saturn!

Sample calculation for Saturn: 9 years ÷ 29 years = 0. 31 years old

Jupiter	12 years	______
Saturn	29 years	______
Uranus	84 years	______
Neptune	165 years	______
Pluto	248 years	______

INSTRUMENTS
Telescopes

Concept: Astronomy has been helped tremendously by the invention and use of the telescope, an instrument which enables greater visibility by enlarging and brightening dim objects.

Difficulties: Telescopes are not easy to use. Very large telescopes provide incredible views of the celestial bodies and even far away objects, but small telescopes can be frustrating. Even when all works well, the image is often no more than a tiny speck. Do not build up students' expectations about what they will see if you try this activity. The purpose here is to introduce students to the notion that astronomers and all other scientists rely on instrumentation for much of their information.

Relationships: The planets of the solar system were first explored using telescopes located on the surface of the Earth. Today, we have a telescope based in space, the Hubble telescope, which orbits the Earth and provides a view of the cosmos free of the blanketing effect of the Earth's atmosphere.

<u>Telescopes</u>

Preparation: Prepare lenses mounted on cups (see p.5 in GEMS, **More than Magnifiers)**

Description: Students will explore the optical properties of telescopes using lenses and objects. (Do this activity after doing **Lenses**).

Hook: Tell the children that Galileo was the first person known to point a telescope at the sky and make observations, and that what he did eventually changed the way humans viewed their place in creation. Before that, terrestrial telescopes were used mainly in navigation, and Galileo was the one to suggest that also. The first telescopes were treated more like toys-interesting items with no real purpose. Others may have pointed a telescope, but Galileo was the first to record observations and get his results printed.

Materials: 10 single-convex and 10 double-convex lenses (provided), 20 paper cups, tape, lamp with no shade, student activity sheet (p. 28 from **More Than Magnifiers**)

Procedures: This activity is very well described in GEMS **More than Magnifiers,** pages 23 - 28. Each student needs the activity sheet found on page 28, along with complete directions and a lot of support and information. NOTE: This activity should be done after the investigation of lenses which is the next theme in this unit. Look over the GEMS book to get a good idea of the activities and procedures before you begin. All activities should be attempted beforehand by the teacher to work out problems and to ensure that you have all the needed materials spaced correctly about the classroom.

Extensions: Actually making a telescope is not a great deal more difficult than the activity that students have just completed. Encourage them to get old paper tubes from carpet rolls or wrapping paper and try to build a working model of a telescope. They will be amazed at how simple it is to build a low-power instrument. Watch for a time when you can see the moon during the day (about a week after the new moon). Take the children outside and let all look at the moon through binoculars.

SPECIAL INTEREST

Lenses

Concept: Optical instruments including telescopes, binoculars, microscopes, movie projectors and corrective glasses all use lenses to alter the paths of incoming light to provide images not available to the unassisted human eye.

Difficulties: Lenses are incredibly common and just as incredibly difficult to use. Have students begin to look for lenses in use in the everyday world, like glasses, water drops etc. It takes quite a bit of time to explore lenses and their effects, so do not build up student expectations.

Relationships: Some telescopes use lenses to enlarge the images of the planets and moons. The Earth's atmosphere acts like a lens to distort the light coming from objects. Examples can be seen in mirages (or "witches' water" on the highway), and in the twinkling of stars and planets, especially near the horizon. Planets above us twinkle less than do stars because they are bodies of visible dimension, though they appear small from Earth. Stars are so far away that even magnification doesn't change their appearance. They appear as points of light, easily distorted by layers of air.

Powers of magnification

Preparation: Prepare lenses mounted on cups (see p.5 in GEMS, **More than Magnifiers)**

Description: Students will explore how lenses work to magnify objects.

Hook: Fill a jug or large clear juice bottle with water and hold it in front of some writing or newspaper. Ask students how the jug of water makes the letters change size and shape. They might mention that the water makes a lens shape. Save the jug and writing to repeat at the end of the activity to see if students have a better understanding of the process of magnification.

Materials: 10 single-convex and 10 double-convex lenses (provided), paper cups

Procedures: The procedures for this activity are clearly described on pages 9 - 13 of GEMS **More Than Magnifiers**. There is much good background information included in the publication as well. The important objective from this activity is to allow students to be comfortable and familiar with magnifiers as instruments, and to provide a basis for the telescopes activity in this unit.

Extensions: The activities that you have not done in **More Than Magnifiers** would be excellent.

Have students in groups do a "LENSES" Scavenger Hunt. Make a list of everyday things that use lenses. Or send older students out to find things that have lenses in them. Instead of bringing back the lenses get them to go around the school and make a list where they found these. Have them find out where the closest public telescope is to your school.

UNIT C

UNIT C
Stars and Gravity

Stars and Gravity has been designed to introduce students in grades 5 and 6 to astronomy concepts dealing with:

- the force of gravity and orbital paths;
- star formation, their evolution, and the classification of galaxies;
- the importance of the presence of solar system debris; and
- the use of light as a source of information.

Organization and sequencing

Each unit in *Astronomy* contains activities and materials centered on six topics: Earth; Solar System; Stars; Motions; Instruments; and Special Interests. Each topic develops one or more concepts and can be related to one or more of the other concepts in the same unit. The concepts developed under each of these topics of *Stars and Gravity* are described below.

Title	Earth	Solar System	Stars	Motions	Specials	Instruments
Stars and Gravity	Which Way is Down?	Debris	Life History of a Star	Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra

The conceptual strands and the activities for each of these areas are discussed in detail later. Reading this information will help you plan a related and focused sequence of activities for your students. In addition, several potential difficulties your students might have exploring these ideas are mentioned. You should informally discuss the concepts with your class before you begin the activities to see just where your students are in their understandings, or to look for areas of potential difficulty which we failed to mention.

Conceptual background for the activities

Stars and Gravity contains activities centering on two extremely important conceptual strands which form a major portion of the theoretical basis of Astronomy:

1. the forces of attraction or gravity; and
2. the significance of the emissions of the stars.

1. The forces of attraction or gravity

The Force of Attraction: Even though we are all familiar with the effects of the force of gravity, nobody knows what it is. Sir Isaac Newton resolved this by: 1) recognizing that the motions of the planets and the motions of apples on Earth are basically the same and 2) by describing them mathematically. Using this mathematical description, Newton was able to account for motions of not only planets and apples, but comets, rifle bullets, tides and nearly everything that moves in the heavens or on Earth. It was powerful and convincing and we continue to use Newtonian ideas to describe how the everyday world works.

Newton described gravity as the mutual attraction between any two masses. The amount of mass and the distance between them could account for their mutual gravitational attraction. The attraction of the Earth's mass for our individual masses, as well as the masses of our cars, trees and the atmosphere, account for the fact that we do not fly off the rapidly spinning sphere of the Earth. The attraction also accounts for the fact that all objects unimpeded fall to the surface of the Earth. In **Which Way is Down?**, students explore their understanding of the attraction of the Earth for objects, even those dropped on the "down under" side of the planet!

But if we leave the surface of the Earth and move into space, other masses begin to have an attraction. There is the largest mass relatively nearby, the sun, whose gravitational attraction holds the planets in their orbits. The planets, in turn, hold their moons and other débris in orbits around them. The massive sun has a gravitational effect on even very distant bodies, like the comets waiting far beyond the orbit of the furthest planet. The gravitational attraction of the mass at the center of the debris cloud from which the sun and planets developed created the solar system. Similarly, the gravitational attraction of the huge mass of stars at the center of galaxies hold them together and produce a variety of shapes. The life history of a star or a galaxy is dependent in large measure on their initial mass and its gravitational effect on nearby bodies.

2. The significance of the emissions of stars

Emissions: The second theme explored in this box is about the role that energy emissions from stars has played in informing us about the chemical composition of stars and galaxies and the life history of stars. The color and spectral lines of these emissions tell us what they are made of and how old they are.

The energy emitted from stars depends on their mass and their composition. Astronomers have developed a theory to account for the fact that stars have different colors and spectra. As stars form and age, the changes that occur within them are signaled by changes in their emissions. Astronomers believe that blue stars are young stars. Red stars can be either old or young. Stars will age differently depending on whether they are small mass (red dwarf), medium mass (yellow star like the sun), or very massive (blue giant) stars.

According to theory, each of these three types of stars begins as a concentration of gas and dust brought together by gravity. For the proto-star, the energy source is gravitational contraction. Just as a bicycle tire gets hot as you put more air into it, the cloud of gas becomes hotter as it is compressed more closely by gravity. When the central temperature and pressure within the gas cloud are both very high, nuclear fusion begins, and the star begins to "shine." This is a normal star. Getting to the fusion point takes longer for stars of smaller mass because there is less gravity. When the hydrogen at the center of the star is used up, the star goes into the next stage in its life history, becoming either a red giant or red supergiant depending on the mass of the star. Blue stars don't stay blue very long because they fuse their fuel at very high rates and they quickly use up their hydrogen. After the hydrogen is used up, they will begin to fuse helium. When the helium at the center is used up, it begins to fuse even heavier elements. Eventually, the red supergiant explodes when it tries to fuse iron, a very heavy element. The leftover remnants of the explosion, depending upon the mass, are either a neutron star or the higher-mass black hole. All the heavier elements were produced by this successive fusing process in the cores of stars!

Less massive stars become red giants when they begin fusing helium. They can't fuse many heavier elements because they don't have enough gravity to bring the interior temperature to a hot enough point. The red giants "puff" off their outer layer, which forms a planetary nebula, and leaves behind a white dwarf star. The white dwarf slowly cools off to become a black dwarf. All the gasses and particles thrown away by stars as they age get recycled into the clouds (nebula) and later become part of new stars and planets that orbit them.

When our solar system formed from a nebula, proto-planets, proto-moons, and debris surrounded the proto-star that eventually became our sun. Objects near the sun were heated such that the light (less massive) gasses were blown away. At greater distances, the cold, light gasses were retained by the giant planets. This interpretation of the formation of the solar system explains why the composition of the objects in the solar system changes with increasing distance from the sun.

The sun and other stars like it will be a main sequence star for about 10 billion years. Our sun, a middle-aged star, is now about 5 billion years old. During this time, its output of energy has been fairly constant. It is the energy from our sun that makes life possible on Earth.

Stars and Gravity	**Which Way is Down?**	Debris	Life History of a Star	Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra

EARTH

Which Way is Down?

Concept: Objects near the Earth are acted on by the Earth's gravitation field, created by the attraction of masses to one another. Gravity is the force that holds us down on the surface of the planet and prevents the atmosphere from escaping. Scientists are not completely sure how gravity relates to other forces. The consequences of gravitational attraction on Earth, however, are well known and predictable. All objects are pulled toward the Earth until some mass or force intervenes.

Difficulties: Most people think of gravity as the force that was discovered by Newton when the apple fell on or near him. Actually, gravity was as obvious to the ancients as it is to us. Newton's famous breakthrough was that he realized the moon was acting just like an apple would if there were no ground to stop it: fall and fall and fall some more. Furthermore, Newton argued, every mass has a gravitational attraction. Small masses, like human beings, exert extremely small gravitational forces on one another. The moon, smaller than the Earth, also has a smaller gravitational attraction. However, its impact can be felt even on the Earth in the form of tides in the ocean. The sun is much larger and exerts a substantially larger force: enough to keep the Earth in orbit. But the sun is much further away than the moon, so its impact on tides is much reduced, though it can be measured.

Relations: Gravity is a pervasive force throughout the universe. **Galaxies, stars, planets, moons, comets** and even pieces of paper are acted on by gravity. The larger the mass, the greater the attraction it exerts on other objects. **Orbits** are affected by gravity, and the **life history of a star** is determined by its original mass and gravitational force. **Debris** in the solar system is thought to be material that was too far away or too small to be drawn into the gravitational "pools" that created the sun and the planets.

The Earth's shape and gravity

Description: Students explore their understandings of the relationship between the Earth's shape and the effects of gravity on its surface.

Hook: Generate a list of "The Effects of Gravity" with your students. Accept all answers. Ask them what the gravity is like on the moon.

Materials: GEMS, Earth Moon and Stars (Activity 2, pp. 9-15), copies of p. 14 for each student as well as another copy for each of 8-10 groups, globe or round ball for each group, roll of tape or small bowl to hold globe

Procedures:

1. Read the activity in GEMS Earth Moon and Stars carefully to be sure that you understand the tasks and the ideas. Students are likely to ask all kinds of strange questions about this activity, so take the time to think it through.
2. Have each student spend about 10 minutes individually answering the questions on the activity sheet. This step may be skipped, but it does help stimulate student thinking before the group activity. Collect the responses.
3. Break students into groups of 3-5 students and hand them a second response sheet to be filled in by the group together. Be sure to indicate that the answers given should be carefully considered by the group, and if there are major differences of opinion about the correctness of any answer, a "minority report" can be included which describes the differences. Answers should be justified.
4. Lead a class discussion about the questions. Do not propose any answers and do not indicate correctness of student responses. Try to get students to reach a consensus for each question and to justify their views. At the end of the discussion about each question, have students commit to one of the solutions proposed.
5. Discuss the solutions to the questions based on the notion of down as toward the center.

Extensions: Have students consider the force of gravity on the other planets with a "What Gravity Means to Me" essay that can be serious or humorous.

Stars and Gravity	Which Way is Down?	Debris	Life History of a Star	Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra

SOLAR SYSTEM
Debris

Concept: Besides the planets and their moons, the solar system contains millions of small objects which can be lumped together under the category of debris. Comets, asteroids, meteoroids, and dust particles, as well as the famous rings of Saturn and the other gas giants, are common types of debris encountered in space. Solar system debris is thought to consist of debris cloud remnants from which the proto-sun was born.

Difficulties: Students often consider space to be an empty vacuum. It is in fact filled with gases, solids and complex compounds of elements. Some scientists believe that life on the Earth came from complex compounds first brought to Earth by meteorites. It is difficult for students to understand the time and distance scale of the universe, and the minute scale of debris may seem insignificant by comparison.

Relations: Gravity pulls debris into orbits around the Earth and some of this debris falls into the Earth's atmosphere. Debris from exploding stars is the source for material for the formation of new stars. Virtually all of the elements we know to be present on the Earth except hydrogen and helium are thought to be the products of nuclear reactions inside long-dead stars that were ejected by massive explosions.

The comet game

Description: Students play a high energy game where they model the position and motion of a comet's tail as it orbits closely around the sun.

Hook: Have students make a quick drawing of a comet. Ask several of them to explain their drawings and what they know about comets' tails.

Materials: a Hula Hoop or loop of string to make a sun disk "base," a long loop of string to lay down an orbital trail around the sun ("it") for comet to follow.

Procedures:

1. Choose one or two students to be "it" (the sun). The "it" stands inside the Hula Hoop or string loop and cannot leave.
2. The rest of the students should form teams of about 10 students to represent comets. One student forms the head of the comet, and the others hang on in a line around each others' waists to form the comet's tail.
3. The head of the comet is immune to the "its" touch, but all other players are fair game. As the line of students representing each comet nears the sun circle, the "it" attempts to reach out and tag the students in the tail. The students in the tail need to keep the student head between them and the sun. After each "orbit" the head drops to the end of the tail and the next student takes their place.
4. If students break off the tail, they are out of the game. If the comet gets down to only two students, they switch with the students playing "it," and the game resumes.
5. Sit down with students after playing the game and discuss the problems they had playing the role of the comet's tail and always facing away from the sun. A comet's tail is formed by the breaking off of small particles as the head (coma) is heated by the sun, and the particles are blown away from the sun by solar wind. The direction of a comet's tail is always away from the sun as a result, rather than streaming behind the comet's path.

Extensions: Using encyclopedias or other reference books, look at the historical representations of comets or how they have been depicted or described by different cultures. For example, there is a picture of Halley's Comet in the Bayeux Tapestry which was made in 1066.

Resources: Poster, "Comets"

Collecting rocks from space

Preparation: Place a pan out during a rainy evening or day and collect at least one cup of rain water. Ask students to collect rain water as well. Place the pan on a chair or table outdoors so that dirt doesn't splash into the water and use a funnel to increase the collecting surface.

Description: Students will collect particles that may be micrometeorites from rain water.

Hook: Who has seen a falling or a shooting star? Why do they light up as

they enter the Earth's atmosphere? What happens to the tiny pieces of the exploding meteorites? They continue to float around the atmosphere as dust, and we might collect some.

Materials: Coffee filters, jar or other containers, magnet (provided), magnifying glass (provided), magnetized needle or nail (both provided), microscope (optional), microscope slide (optional)

Procedures: NOTE: There are many interesting things in our rain water! Use this opportunity to discuss **inference** and **evidence**. There is no real proof that the magnetic materials you collect in rainwater are the result of meteorites in our atmosphere, but teachers of astronomy feel safe in that assumption. You may wish to have a meteorologist or astronomer discuss with your class the findings they make in this rain water analysis activity.

1. Collect rain water samples and store in a clean, closed jar.
2. Ask students to think about where rain comes from. Does rain pass through air as it falls to the ground? Is rain clean? Let them discuss what they know about rain water, such as how acid rain is created by water drops falling through chemicals from factories. If rain drops fell through smoke, would they be sooty? Have the children ever looked closely at snow, which can have quite a bit of particulate matter in it? What are some ways that rain indicates what's in our air?
3. Let the children talk about their ideas and ask them if they think that objects from space may appear in our rain water. How can we find out what's in our rain? One way might be to pass rain water through a fine filter and look at the big particles that won't pass through. Show them the coffee filters and ask how they might set up a way to pour rain water through and filter out particles for study.
4. Let them try their ideas until you have several coffee filters with particles on them.
5. Invite the students to examine the particles with magnifying lenses or a microscope, classifying by appearance. Ask if they can figure out a way to tell if any of the particles are made of iron, a material common in some types of meteorites. One way they may suggest is letting the particles rust, so be ready to let some students set up that test. Another way might be to use a magnet.
6. Let the students try different ways to collect and sort the materials from rainwater that are magnetic, and discuss this inferential evidence of rocks from space.
7. Below is a table indicating when major meteor showers occur. These regular events are related to the Earth passing

through comet debris. It would be an interesting science project to collect rain water samples on a number of different dates and relate the number of particles recovered to the dates below and to weather and other atmospheric events in your region.

TABLE OF METEOR SHOWERS

SHOWER	DATE OF MAXIMUM ACTIVITY	MAXIMUM HOURLY RATE OF METEORS
Quadrantids	January 3	40
Lyrids	April 21	10
Eta Aquarids	May 6	10
Perseids	August 10 - 14	50
Orionids	October 20 -23	20
Taurids	November 3 - 10	13
Leonids	November 16-17	12
Geminids	December 13-14	65
Ursidis	December 22	13

Extensions: Have students write a fable or a myth explaining why we have meteor showers.

Resources from the materials kit:

Official Rand McNally Map of the Moon
Poster, "Comets"
Poster, "Meteorites"

Stars and Gravity	Which Way is Down?	Debris	Life History of a Star	Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra

STARS

Life History of a Star

Concept: Stars are burning or glowing balls of gas that give off heat and light. They are born from clouds of gas and dust. The changes stars undergo as they age are determined primarily by their original mass. Stars are different colors and diameters depending upon their age and mass.

Difficulties: The distances and times involved in stellar astronomy are unfathomable. Stars appear so small, even through telescopes, that they look similar. The vast majority of stars have not changed at all through human history. Most of what we think we know about stars is based on theory.

Relations: The **colors and spectra** of stars show the temperature of the outer layers of the star and their chemical composition. The solar system formed from a nebula of **debris** and gases, a remnant of earlier stars that lived out their existence and disappeared. **Planets, moons,** and debris surrounded the proto-star that eventually became our **sun**. The composition of our solar system changes with distance from the sun.

Birth and death of a star

Description: Students will write a biography of a star after discussing the changes that occur in the lives of small mass (red dwarf), medium mass (yellow star like the sun), or very massive (blue giant) stars.

Hook: Talk with the students about life cycles of organisms that they are familiar with. Tell them that stars have life cycles too.

Materials: Ranger Rick's Nature Scope Astronomy Adventures, page 7-8.

Procedures: 1. Read the guided imagery aloud to students (page 7 of Ranger Rick's Naturescope Astronomy Adventures). This background information can also be found in almost any

encyclopedia. Once students are familiar with the background information, they should be able to identify the major stages in a star's life: Nebular origins, fusion-powered middle life going through the light elements and into the heavier ones, and then exploding into one of a number of alternative final stages.

2. Have students write an invented short biography of a star. The biographies may be illustrated if students wish, and the invented stars should be named.

Extensions: Get students to work in small groups. Have each group write a play about the life cycle of a particular kind of star. Have them include stage cues, costuming, and props, etc. Have groups exchange plays to see if they can perform a play created by another group.

Resources from the materials kit:

Poster, "Galaxies"
Poster, "Horsehead Nebula in Orion"

Stars and Gravity	Which Way is Down?	Debris	Life History of a Star	Ellipses and the Planetary Mystery	Galaxies	Colors & Spectra

MOTIONS

Ellipses and the Planetary Mystery

Concept: The orbits that the Earth and other planets take around the sun were long thought to be circular. However, observational data did not support this belief. Instead, the orbits that best fit the observational data can be shown to be elliptical, some orbits are more elongated than others. Pluto's orbit is so elongated, and so different from the other planets', it is suspected to be a captured body, rather than part of the original solar system. One result of its eccentric orbit is that Pluto's average distance from the sun is greater than Neptune's, yet Pluto is currently and will remain closer to the sun until 1999.

Difficulties: Mathematical ideas often present difficulties for students, and numbers cause them to tune out quickly before they can connect to the concepts demonstrated through mathematics. The effect of mathematical operations such as averaging leads to misunderstandings.

Relationships: The orbit (revolution) of the Earth is slightly elliptical as are the orbits of the moons and planets. Some debris also have elliptical orbits.

The planetary mystery

Description: The stage is set for a "mystery" involving planetary order from the sun.

Hook: Sometimes what common knowledge and books tell us can lead to false conclusions.

Materials: The story below.

Procedure: 1. Tell the students that they have a mystery to solve during the next two astronomy activities. When they think they know the answer, they should write it on a slip of paper with their name and give the slip to you. They shouldn't tell anyone

else what they have written! The question is, "Who is responsible for the astronomer's disappearance?"

2. Read aloud "The Planetary Mystery," below. You may like to post the story for students to read, along with the following chart:

Average Planetary Distance from Sun

Object	Average distance from SUN (km)
SUN	-
MERCURY	58,000,000
VENUS	108,000,000
EARTH	150,000,000
MARS	228,000,000
JUPITER	780,000,000
SATURN	1,430,000,000
URANUS	2,870,000,000
NEPTUNE	4,500,000,000
PLUTO	5,900,000,000

3. When done, go on into the next activity, "Just about average."

The Planetary Mystery

"If something ever happens to me, look for the one named for the most distant planet!"

The mysterious note appeared beneath a stack of papers in the safe of missing astronomer, Dr. Mars del Sol. Detective Herlock Sholmes collected all of her notes in front of her, then spoke into her tape recorder:

> "Famous astronomer Mars del Sol has been missing for three years, now, and the members of his family are insisting that his fortune be divided up amongst them. The only evidence I have found is this note: 'If something ever happens to me, look for the one named for the most distant planet!'
>
> "The brothers and sisters of this odd family are all named after planets of the solar system, and, with this new evidence, I must assume that Dr. del Sol's brother, Pluto del Sol, is responsible for a dastardly deed."

Detective Sholmes turned off the tape recorder and set it down. "Now," she said, "I must call for police assistance to question the brother Pluto."

At that moment, Neptune and Venus del Sol walked into the room. "Detective Sholmes," one said, "Whenever are we to settle this estate? It's obvious that dear brother Mars has abandoned earthly efforts and relinquished his wealth to his loving family!"

"Soon!" Said the detective. "I have a suspect in his disappearance!"

"A suspect! Who?" asked Neptune and Venus del Sol.

" I can't tell you for sure until I look at a Planetary Distance Chart," replied the detective. "Can you show me one?"

"Allow me!" Said brother Neptune, producing an elementary school science textbook. "This book is always good for straight and accurate facts."

"Aha! Now I know!" Said Detective Sholmes.

What did the detective discover? Who is responsible for the disappearance of Mars del Sol?

Just about average

Description: Students explore the concept of "average" by running, throwing, and spelling in different game situations.

Hook: Ask the children who they think is a fast runner, a good thrower and a good speller in the class.

Materials: Outdoor area, a ball of some sort, a metric measuring tape and a stopwatch, and at least one mirror.

Procedures: 1. Show students the following charts and tell them that they will help to complete them during this activity:

Fastest runner

Name	Average time

Best thrower

Name	Average distance

Best speller

Name	Average no. words right

2. Ask students to predict the results for each little contest, before you show them the rules. They can name three different people for each contest. Then begin the three contests, recording three scores for each person involved according to these rules:

Fastest runner: The first measurement is timed individually over a set distance, say, fifty meters. For the second event, one person has to run backwards. Again, the individual times

are written down. For the third race, two of the kids have to use only one leg. Each runner's times are all written down.

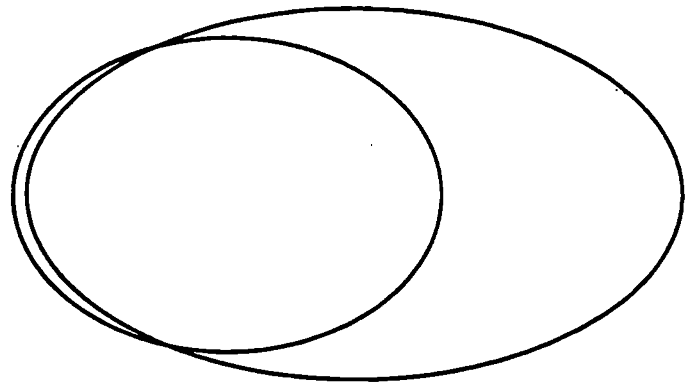
Best thrower: For this "contest," each participant has to throw a ball across the playground, and the distance is measured individually. For the first trial, each entrant throws normally. For the second trial, two of the entrants must throw with their backs to the playground. For the third trial, one thrower must change hands and hold his or her feet still. These results are written down.

Best speller: The three "contestants" will be given a barrage of words to spell, but will take turns looking into a mirror to write. Suggested words for each trial (to be read quickly): TRIAL 1: rough, smooth, breathe, lieutenant, parsley, committee, argument, knowledge, judgment, tough. TRIAL 2: alcohol, doctor, author, sure, senior, vision, explain, circle, paste, although. TRIAL 3: decide, unless, enough, surprise, eighth, quiet, awoke, until, certain, again. When the mirror is used, the students must look at the reflection as they write. This really slows them down.

2. Show the students the data you have collected and proceed with figuring an average for each student. They will protest that the contests were not fair. Show them their data as a range, from low to high, and as an average.
3. Ask, "What might people think about your ability to run, throw, or spell from this average?"
4. Ask, "Where are averages used in astronomy?" Look at some of the posters showing average planet temperatures. What is the range for each one? The average winter temperature in Austin, Texas, is around 60 degrees. Does that mean you won't need a coat when you come to visit in January?

The effects of an average: what's the ninth planet?

Preparation: Enlist at least 3 students to draw on the playground or parking lot these two figures: one ellipse approximately 12 meters across, and a second ellipse that falls within the first ellipse at one end, as shown:



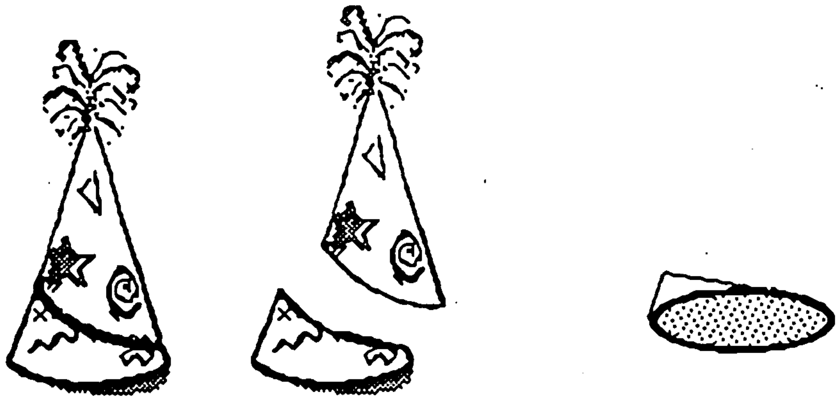
Description: Two chalk shapes are drawn on the playground to represent the orbits of Neptune and Pluto, and student "suns" observe the motion of two orbiters as they change their relative distances from the sun.

Hook: Remind the students of the Planetary Mystery and show them the number of slips of paper you have collected with solutions to the mystery. Tell them you will have many more solutions after today's activity.

Materials: Outdoor area, chalk, string, cone-shaped party hat or rolled paper, marker, scissors

Procedures:

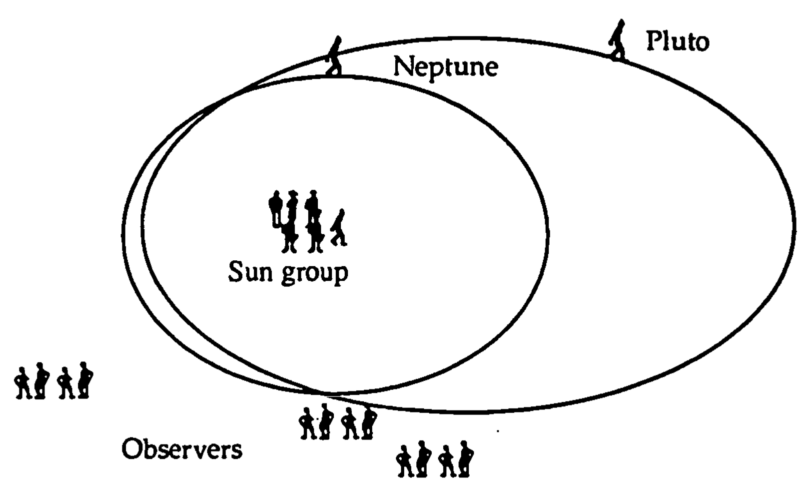
1. Show students the party hat and ask them to describe its shape. The shape described by the open end of the cone is a circle, consisting of points equal in distance from a center axis.
2. Mention that a circle describes most planetary orbits fairly well, but that some such as Pluto are ellipses. Draw for the students a "circle" angled on the cone with respect to the axis, then cut along that line.



the new cut edge is an ellipse

3. Explain that the sun is at the center, where the axis or center point is, but the angle of this new shape has made it an oblong, almost an ellipse.
4. Now the children will form a human model of the solar system's last two planets, Pluto, with an extremely eccentric elliptical orbit, and Neptune, with a smaller and more circular orbit. Ask the children to select which role they'd like to play for the first demonstration: observers, sun group, Neptune, or Pluto.
5. Tell the observers that they are to note anything that is interesting about the planets, and that they should note at least every 30 seconds which planet is closer to the sun. The sun group will stand with their backs together, facing out toward the orbital paths. Neptune and Pluto will each walk around their orbital paths twice, then roles will change.

NOTE: These orbits are not drawn to scale, and Pluto's orbit is actually in a different plane than is Neptune's.



6. Go outside and begin the activity, repeating it until everyone has had a chance to "be" the sun.
7. When you return indoors, give the students one more chance to write a solution to the Planetary Mystery. Hand out the slips of paper and re-read the mystery to them. When someone reports the solution, that Neptune is the ninth planet from the sun, ask them to PROVE IT, especially since the chart of distances shows Pluto as last. Insist that they use the word "average" in their explanation.
8. The explanation desired is that Pluto's average distance from the sun is greater than Neptune's, but the range of kilometers includes a near distance closer than Neptune's. Averages sometimes give a first impression (to people such as detectives) that don't reflect true quantities. Fortunately for Detective Sholmes, and unfortunately for brother Neptune del Sol, data charts are clearly marked when average figures are used!

Extensions: **Making Ellipses:** Have students use closed loops of string and two push tacks as foci to draw different types of ellipses.
Human Ellipses: Construct together a large scale ellipse using classmates as the foci, and a loop of string for a radius that is 30 meters long.

Resources from the materials kit:

Poster, "The Solar System"

SPECIAL INTEREST

Galaxies

Concept: The Milky Way is the name of our galaxy and there are billions of other galaxies in our universe. Galaxies can be classified by their shape; there are elliptical galaxies, spiral galaxies - like our own Milky Way, and irregular galaxies which have no apparent shape. Different types of stars appear in different parts of galaxies.

Difficulties: Galaxies are very difficult for students to understand since they have no concrete models around which to organize their understandings. The immense scale and distances we use to talk about galaxies make them abstractions. And their near invisibility to the naked eye adds to the difficulties children as well as adults have in conceptualizing galaxies. With stars, students at least have the sun as a familiar example. Furthermore, the one galaxy that can be easily seen nightly, the Milky Way, looks nothing like the photographs of spiral galaxies in textbooks and magazines. These difficulties make teaching about galaxies a slow and careful activity.

Relations: Star colors show the temperature of the outer layers of the star. From the theory of stars, astronomers know that blue stars are young stars. Red stars can be either old or young. Over all color distribution in a galaxy shows the history of its star formation.

What is your galaxy?

Description: Students learn several ways to classify galaxies using pictures.

Hook: Have each student take off one shoe and put into a pile in the center of the room. With the students, "classify" their shoes. Show them that there are several ways to classify the shoes. Tell them that astronomers have a "big pile" of galaxies to classify and you are going to look at ways they use to do it.

Materials: Poster of galaxies, pictures from other reference books available.

Procedure:

1. Using color posters, compare the colors of the galaxies to pick out the red/yellow stars and the blue stars. The blue stars show the newest parts of the galaxy; these stars are all young. The centers of spiral galaxies have old stars, mostly red giants. Elliptical galaxies have no gas or dust and, therefore, no new stars. They have only old stars.
2. Tell the students that our solar system (our sun is Sol) is located 2/3rd's of the way out on the arm of our spiral galaxy, the Milky Way. Show them a picture of a spiral galaxy once again and where 2/3rds of the way out would be on an arm of it.
3. Have students design a T-shirt that "advertises" where we live. If possible, have students bring T-shirts from home and use textile paints to make the shirts. They can write on the T-shirt their complete address:

school
district
town
county or parish
state
country
hemisphere
planet = Earth
star system = Solar System
Milky Way
Universe

Resources from the materials kit:

Poster, "Galaxies"
Poster, "Horsehead Nebula in Orion"

INSTRUMENTS

Colors and Spectra

Concept: Light can be thought of a series of waves. Blue light has more energy and shorter wavelengths than red light. Filters block other colors from passing through. Colors of hot objects indicate their temperatures. For example, a hot object that is glowing red is much cooler than an object glowing blue. Spectroscopy is used to find out what chemical elements are in an object. It does this by analyzing what wavelengths are present in the object, usually when it is heated.

Difficulties: Relating colors of objects to their temperature and composition is difficult for children. Most children have not had a good introduction to the electromagnetic spectrum, are unaware of ultraviolet and infrared wavelengths, and think of light as only the visible light we see. Many more questions will be raised in these activities than they address, so you should be prepared to either extend the study of light beyond the activities included here (the **GEMS Color Analyzers** publication will give some clues as to how to do this) or find some way to redirect students' interests away from the topic.

Relations: Stars are different colors due to their physical properties., which also determine their **life histories**. We can get a fair estimate of the age and life span of the stars in our galactic neighborhood based on the analysis of the light we receive from them, allowing us to estimate the percentage of stars which might have planets and the potential for intelligent life forms (see **Is Anyone Out There?** in Unit 4, ***Scales and Measures***).

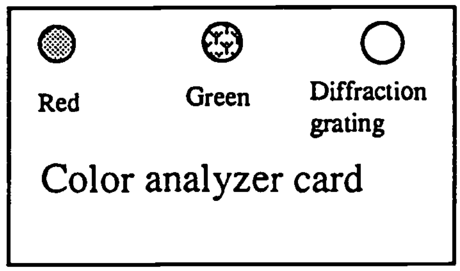
Decoding secret messages

Description: Students use colors to create coded messages and color filters to read them.

Hook: Make the secret "help" message found on page 19 of Color Analyzers. Tell students you found the message in the school

office, but you do not think that anyone would really be in that much trouble in the office (ha ha) and that maybe, there is a secret, hidden message contained within the "help." Let them speculate what it might be and then give them the filters to see if they can find the hidden message. Use a coffee filter to demonstrate how filters allow some things to pass but not others.

Materials: Color analyzer cards (provided), copies of secret message data sheets, crayons or markers



Procedures:

1. Instructions for this activity are clearly described on pages 5 -10 of the GEMS Color Analyzers book. The secret message data sheets can be found on pages 11 - 15. This activity draws students into an investigation of color and light.
2. When students have worked with light and color for a while, stop them and explain the following. Astronomers use the properties of colored light to collect a wide variety of information about stars and galaxies that are too small for our unaided eye to even see. Astronomers use color filters to estimate the temperature of a star. If a star's apparent magnitude is measured in red light and in blue light (using the appropriate filters), the difference of these measurements indicates the temperature of the star.

Extension: Use the color analyzer to examine pictures (or slides or posters) of astronomical objects. The picture on the back cover of Color Analyzers is a good example. The green filter allows the stars to be seen more easily; the red filter shows the dusty nebulae better. The nebulae where new stars are being formed is often red in color. Nebulae around hot, young, blue stars appear blue in color. Astronomers use different filters on their telescopes to study these objects. You can use the color analyzers to look at other posters in the kit. Two extra objects that are fun to observe with the filters and diffraction grating are a string of Christmas tree bulbs of various colors and a single tube fluorescent lamp (e.g. Radio Shack Mini Fluorescent lamp 61-2734, which shows a bright emission line in addition to the continuous spectrum).

Buy a 3-D comic book and let students see how red and blue lines are used to create the images which will appear in 3 dimensions when filters of red and blue are used.

The colors in light

Description: Students investigate a variety of types of light with diffraction gratings to determine what are the components and how they differ. The diffraction grating is the main component of an astronomer's spectrograph.

Hook: Ask the students if they have ever noticed that street lights (security lights) are not exactly white in color. Ask them what colors of lights they have seen (bluish and orangish). Tell them that even white-looking light is composed of different colors.

Materials: GEMS Color Analyzers book, color analyzer cards, copies of student data sheet, p. 29

Procedures: The procedures for this activity are well described in GEMS Color Analyzers, on pages 23 - 28. Be sure to leave the light bulb on in the center of the room while you discuss the students observations so that they may check on their observations and those reported by other students during the discussion. It helps to darken the rest of the room; use shades, if available.

Extension: There are a number of activities that you could use to further explore light and color. You could talk about rainbows and prisms, chromatography (see GEMS Crime Lab Chemistry), waves and reflection, and so on. This activity could be integrated into an art activity, as well, looking at how lights of different colors reflect from different-colored surfaces and combine to make new colors. Making secret messages with colored markers is challenging for students.

Resources from the materials kit:

Astronomy Adventures "Splitting Starlight" page 14.
Poster, "Galaxies"
Poster, "Horsehead Nebula in Orion"

UNIT D

UNIT D
Scales and Measures

Scales and Measures has been designed to introduce 7th and 8th grade students to astronomy concepts related to:

- mathematical perspectives of the cosmos; and
- human perspectives of the cosmos.

The measure of light speed and the value of exponential powers of ten allow students to discuss the scales of the solar system, the galaxy and the universe, to explore the possibility of intelligent life elsewhere, and to calculate the distances to the planets and stars. The human perspectives activities focus on the impact of space exploitation, the explanation for the phases of the moon and the best approach to take to predict the existence of other intelligent life forms.

This section would be enhanced by a team effort between mathematics and science teachers, so that the numeric concepts presented could be reinforced in both classrooms.

Organization and sequencing

Each unit in *Astronomy* contains activities and materials centered on six topics: Earth; Solar System; Stars; Motions; Instruments; and Special Interests. Each topic develops one or more concepts and can be related to one or more of the other concepts in the same unit. The concepts developed under each of these topics of *Scales and Measures* are described below.

Title	Earth	System	Stars	Motions	Specials	Instruments
Scales & Measures	Phases & Perspectives	Planetary Scales	Is Anyone Out There?	Speed of Light	Lunar Mining	Powers of 10

The conceptual strands and the activities for each of these areas are discussed in detail later. Reading this information will help you plan a related and focused sequence of activities for your students. In addition, several potential difficulties your students might have exploring these ideas are mentioned. You should informally discuss the concepts with your class

before you begin the activities to see just where your students are in their understandings, or to look for areas of potential difficulty which we failed to mention.

Conceptual background for the activities

Scales and Measures has two related conceptual themes:

1. mathematical perspectives, focusing on the heavy mathematical emphasis in astronomy; and
2. human perspectives, centers on the need to maintain a human, Earth-bound connection to the tremendous times, distances, and ideas of astronomy.

1. Mathematical perspectives

Mathematical perspectives: Astronomers work with extremely large and extremely small numbers. It is important to remember that although the numbers are very complex, the actual mathematical operations used are not difficult, usually no more than simple multiplication and division. Stress this for your students. However, as simple as the calculations might be, the numbers are scary all by themselves. For example, the diameter of our own galaxy, the Milky Way, is about 10,000,000,000,000,000,000,000 meters, or ten septillion meters!! The most abundant element of the universe, hydrogen, has a nucleus with a diameter of approximately 0.0000000000000001 meters, or one quadrillionth of a meter! These are very difficult numbers to work with. Errors can easily be made with so many zeros, and it takes a lot of time to count them all!

Powers of ten: Fortunately, there is a simpler and much more efficient way to deal with numbers like these, using the exponential powers of 10. Exponents are the small raised numbers which indicate how many times a number should be multiplied by itself. A common exponent is 2, which indicates a number times itself: $5^2 = 5 \times 5 = 25$; $4^2 = 4 \times 4 = 16$. Increasing the number of the exponent increases the number of times you multiply a number by itself: $5^3 = 5 \times 5 \times 5 = 125$. Using a base number of 10 makes things very simple; for each increase in the number of the exponential, the scale increases by ten times, or one order of magnitude. For example, a dime is worth 10^1 pennies, a dollar is equal to 10^2 pennies, and a hundred dollars is 10^4 pennies. By allowing scientists to use the same unit of measure for different scale objects, exponential numbers make the communication task much easier. Negative exponents describe the number of zeros to the right of the decimal point. 10^{-1} pennies equals 0.1 pennies, or 1/10 of a penny Another way to think about negative exponents is to remember that they represent a growing number in the denominator of a fraction: 10^{-2} equals 1/100; 10^{-4} =

1/10000. The activity **Powers of 10** enables students to experience the differences in scale between the smallest and the largest measures known today in the universe, and how they relate to the human scale. An extension explores the terminology employed for many of the exponential units.

When compared with very large numbers like galactic distances, the planets seem like near neighbors! You may wish to do **Planetary Scales** before **Powers of 10**, although they can be done in either order. The scale model of the planetary distances provides a concrete look at the relative distances between the planets. It also describes the size of the planets not only in relation to one another, but in scale to their distance from the Earth and sun. No wonder they look so small in the night sky!

The speed of light: The speed of light is another way of measuring large distances in astronomy. A light-year (ly) is the distance light will travel in one year. Light travels through space at a constant speed of 300,000 km/sec. This is a nice round value for students to remember for light speed. Once they are familiar with this number, students can calculate the distance to various celestial landmarks. The activity has students calculate the time light will require to travel from the sun to the planets, and from the planets back to Earth. By adding these numbers, students can determine how long ago the reflected light we see at night from Jupiter left its original source, the sun.

Light years are usually reserved for distances far greater than the local solar system. To use light years for measurements in a solar system scale is much like measuring the walls of your classroom in miles.

Human Perspectives: Astronomy may be the study of every thing beyond the Earth's atmosphere, but it is entirely a human undertaking. The activities in the conceptual theme Human Perspectives encourage students to think about some of the ways that the human perspective has influenced the way we see "our" universe.

Earlier, the difficulties students encounter from the regular apparent motion of the sun across the sky were described as a problem of perspective: the sun was seen as an overhead movable phenomena while the Earth was fixed under the sun. This conceptual organization of the sun/Earth relationship left no place for the sun to be at night, and prevented students from developing more productive models of the Earth as a cosmic body. The same difficulty occurs with the moon and its phases. Everyone knows that the moon changes shape from night to night, going from full to new and back with some regularity, but why and how this happens are mysteries to most of us. Thinking of the moon as the nighttime equivalent to the sun is one major reason for these difficulties. In the activities offered in **Phases and Perspectives,** students are encouraged to understand the Earth/moon system as having a third cosmic partner, the sun. The phases of the moon as seem

from Earth are directly linked to the positions of the sun and the moon relative to the Earth-bound observer. Recognizing that the moon can often be seen during the daylight hours, and that sometimes it is not visible at all during the night helps students overcome the notion that the moon is the opposite to the sun.

The light from the moon is reflected from the sun, and so it offers no warmth and insignificant energy. The moon is also significantly farther away from the Earth than most students think, nearly 30 Earth diameters. Recognizing the distance to the moon and the relation of the moon to the sun enables students to begin to build a model of the moon's phases. An observational exercise helps them understand the regularity of the phases of the moon.

Once students grasp the distance and size relationships between the Earth and the moon, the scale distances and sizes of the planets and their moons can be more easily understood. The distances between the planets do have a regularity, first noticed long ago by and named after the astronomers Titius and Bode. The Titius-Bode Rule can be expressed by the mathematical formula - $(x + 4)/10$. If we use values of x from a series of numbers 0,3,6,12,24...etc. , the solution will represent the approximate distance of most planets from the sun in astronomical units, the distance from the sun to the Earth. Try it for Earth, the third planet from the sun and the third number in the series above: $(6 + 4)/10 = 1$.

2. Human perspectives

Mathematical probability is an important part of astronomical mathematics. One idea students will commonly express when dealing with the large scale of the universe is to wonder if in fact we are alone as the only "intelligent" species in the vastness of space. In discussions, students will vary in their arguments, but by and large the conclusion most students will reach, (in fact that most people will reach) is that we will never discover another intelligent life form. The activity in probabilistic thinking, **Is Anyone Out There?**, challenges that common conclusion, and demonstrates that the mathematical results can be strongly influenced by the assumptions that go into any problem solving effort. Most arguments in natural science are not about the actual results scientists report, but about the validity of the assumptions that went into shaping the calculations and the meaning of the results for the theories that support those assumptions.

The possibility of intelligent life somewhere out there raises the possibility of eventually meeting that life. While this may seem mind-boggling, the issues it raises are actually of more immediate usefulness. It may not be in the so distant future that the resources of space are economically exploitable. Early attention will probably focus on the moon.

The activity **Lunar Mining** explores some of the issues that space exploitation will raise. While the situation is not identical to the exploitation of the new lands discovered during the period of European expansion, the issues are very similar. Who will have access to the technology and benefits of space exploration? Does it matter if the resources are not evenly distributed among the Earth-bound? The debate should be lively and will encourage a very serious thoughtfulness among many students about issues they are likely to one day face as the decision makers of our society.

EARTH

PHASES AND PERSPECTIVES

Concepts: The moon orbits (revolves around) the Earth every 28 days. The light we see from the moon is reflected sunlight. The sun illuminates exactly half of the moon at any one time, just like it does the Earth. However, it is only during full moon that we see the entire half lit by the sun. As the moon orbits around the Earth, its position in relation to the sun also changes. This causes the different lunar phases which we see from Earth. The phases of the moon, therefore, are the result of the changing triangular relationship among the positions of the Earth, the moon and the sun. The distance from the Earth to the moon is 30 Earth-diameters, and the moon's diameter is 1/4 an Earth diameter in size. Gravity on the moon is 1/6 Earth's gravity.

Difficulties: The moon is often thought to be the opposite of the sun. Many students will think it shines at night, and will not understand the difficult concept of viewing the phases of the moon as due to the changing triangular relationship among the positions of Earth, moon and the sun.

Relations: The moon's spherical nature and relative position determine its phases. The Earth/moon system can be compared with the other **planets** and their moons. Note that only Pluto has a moon which is as large compared to its planet as our moon is compared to the Earth. The activity in **Planetary scales** concretely illustrates the distances and sizes of planets and moons.

Earth/moon model

Preparation: Ask students to bring in one or two balls of various sorts from home and borrow some from the physical education teacher. Calculators, also, may help students with this activity.

Description: Students explore the scale relationships between the Earth and the moon.

Materials: 12.5 cm diameter styrofoam ball (provided), 3.125 cm diameter styrofoam ball (provided)

Hook: Show students a road map of your state. Locate your town on the map and ask how far away, on the map, would the state capital be. Measure it in centimeters and convert to kilometers. Show them the scale on the map and ask them why it is important when talking about distances to use a scale.

Procedures:

1. Place all of the balls in front of the classroom. Ask students to work in teams to select two that best approximate the scale size relationship between the Earth and the moon. Let them use books and charts, then defend their choices, eventually pointing out that the Earth is 4 times bigger than the moon.
2. Give each of two students one of the two balls which are scaled to the diameter of the Earth and the moon (One should be about 12.5 cm in diameter; the other about 3.125 cm.)
3. Ask them to stand about as far apart, in scale of course, as they think the Earth and the moon are from one another.
4. Ask for other input on whether or not the two students and their models should be closer or further apart. Ask students to provide reasons for their arguments.
5. When the class agrees that the distance looks about right, measure the distance in centimeters between the Earth and the moon. Students may disagree, and arrive at two or three independent solutions. Allow students time to elaborate on their reasoning. Number and measure each proposed solution.
6. Make a table of values on the board or on an overhead which includes the following information:

Position	Distance in cm (X)	Dist. in Earth diameters, (X/12.5)
Position 1		
Position 2 (if needed)		
Position 3 (if needed)		

7. Ask students what type of information they would need in order to accurately place the two spheres. If students are unable to answer, you might suggest that they think about the scale relationship between the two spheres. The Earth's diameter is 4X that of the moon, 12.5 cm vs. 3.125 cm

HINT: The solution is actually quite a bit less complicated than you might think. If you know the diameter of the Earth and the diameter of the moon and the actual distance between the two spheres, a simple ratio can be derived as follows:

$$\frac{\text{distance from the Earth to moon}}{\text{diameter of the Earth}} = D \text{ (distance in Earth diameters)}$$

Since the sphere representing the Earth is about 12.5 cm in diameter, the answer to the above problem, D, times the scale diameter **12.5 cm**, equals the scale distance. The following table shows the actual values of distance and diameter, and the approximate values we'll use in this activity.

	Actual	Approximate
Diameter of Earth	7927 mile	8000 mile
Diameter of Moon	2160 mile	2000 mile
Distance Earth to Moon	238,968 mile	240,000 mile

Note that the diameter of the Earth is about 4 times larger than the diameter of the moon. If you select a ball which is a certain diameter to represent the Earth (for example, 12.5 cm), the ball needed to represent the moon will be 4 times smaller (in this case, 3.125 cm).

To decide how far apart to place the Earth and moon spheres, divide the distance between them (240,000 miles) by the Earth's diameter (8,000 miles) to get a value D = 30 Earth diameters.

$$\frac{240{,}000 \text{ miles}}{8{,}000 \text{ miles}} = D = 30 \text{ Earth diameters}$$

There are 30 Earth diameters between the Earth and moon. If you were using a 12.5 cm sphere for the Earth, then the two spheres would be

12.5 cm x 30 = 375 cm or 3.75 meters apart.

8. Once you have worked out the distance mathematically to be about 30 diameters, it is easy to measure accurately the scale relationship between the two spheres.
9. Ask students to estimate the sun's position relative to their model. Do not be surprised if students place the sun between the Earth and the moon!

Extension: Have students model the distance of the sun from the Earth using Earth diameters. Let them work our the way to figure it out. The sun is 93,000,000 miles from the Earth.

$$\frac{93{,}000{,}000 \text{ miles}}{8{,}000 \text{ miles}} = \text{Distance} = 11{,}625 \text{ Earth diameters}$$

Multiply this by 12.5 cm (Earth's diameter in our scale). 11,625 X 12.5 cm = 145,312.5 cm

Divide by 100,000 (cm to m to km) to get kilometers = 1.45 (rounded)

In the model, the moon would be 3.75 meters from the Earth and the sun would be almost 1 1/2 kilometers distant!!! Get them to set their model up in the community with the Earth and the moon located your room. Make a yard sign with the sun on it and place it (with permission) about 1.5 km away along the students' most familiar route to school.

For another extension, compare the Earth-moon system with the other planets and their moons. Note that only Pluto has a moon which is as large compared to its planet as our moon is compared to Earth.

Lunar observer

Description: Students will collect observational data of the moon's appearance and distance from the sun and explore the patterns of the lunar cycle.

Hook: Did you ever hear the saying "Once in a blue moon..."? Does anyone know what it means?

A "blue moon" occurs when there are two full moons within the same calendar month. But commonly the term means "once in a great, long while." In this activity we will observe the phases of the moon to understand why "blue moons" are so rare.

Materials: GEMS Earth, Moon, and Stars Activity 3 (Observing the Moon), pages 17 - 22, 2 large sheets of butcher paper, felt markers, tape to hang the paper.

Procedures: The procedures for this activity are well described (and illustrated) in GEMS Earth, Moon, and Stars Activity 3 (Observing the Moon), pages 17 - 22. This activity is an excellent introduction to the phases of the moon. However, it requires some planning ahead, since it does take an entire month to follow the moon through a cycle. If you plan to study this for only one week, then be careful to choose the correct phases to

study. For example, the moon is very difficult to find when it is close to new and many students will become discouraged. Also, you wouldn't want to send them out in the early evening to observe the third quarter moon, since it doesn't rise until midnight! It would be good for you to do the activity the month before you have the students do it so that you will be familiar with when and in what part of the sky you can see the different phases of the moon.

Extension: Have students find out about different words which we have in our vocabulary that come from the word moon or luna. You may also wish to have students look into local folklore and myths about the moon.

The Moon has been the source of many mythological characters and stories. You may have students search for explanations in other cultures for the phases of the moon, and report back to the class.

Lunar phases

Description: Students model the phases of the moon with a model moon-on-a-stick and a light source for the sun.

Hook: Tell students that the name of this activity is "Lunasticks" and have them guess what they are going to do.

Materials: GEMS Earth, Moon, and Stars Activity 4 (Modeling Moon Phases), pages 23-27, ping pong balls mounted on golf tees, one light fixture for the middle of the room.

Procedures: The procedures for this activity are well described in GEMS Earth, Moon, and Stars Activity 4 (Modeling Moon Phases), pages 23-27. It will work best if you have collected your own data as in the activity just preceding this one, **Lunar observer.**

Extensions: Ranger Rick **Astronomy Adventure** "Moon Madness" (page 46 and 51) is fun for the students to make as they learn the sequence of moon phases and relationships among the Earth, sun, and moon positions. Note that the flip book pictures are not to scale.

Resources from the materials kit:

Phase of the Moon Calendar
Official Rand McNally Map of the Moon
Posters, "The Solar System" and "The Full Earth"

SOLAR SYSTEM

Planetary Scales

Concept: The planets orbit the sun in a particular order. The distances between them and their sizes relative to one another are difficult to conceptualize. Measuring out scale models helps show the relative sizes of things in the solar system.

Difficulties: Scale models may give concrete understandings, but the planets are never lined up in quite the same way this activity indicates. While the activity doesn't show the actual relationships of the planets in space (since they are always moving, and seldom line up directly), it does show how big the solar system is.

Relations: The **planets orbit** the **sun** at different distances. **Stars** are at vastly greater distances away from us as compared to the planets. The scale model of the Big Dipper (see **Modeling constellations**) indicates how the stars in a constellation may actually be unrelated except by our particular **perspective**.

Planetary scales

Preparation: You may wish to use calculators if your students are weak in using metrics and decimal numbers. Also, this activity requires students to complete some calculations on a data table. You may wish for them to do those calculations for homework before you do this activity.

Description: Students make a scale model of the distance of the planets from the sun.

Hook: Remind students that when they built a scale model of the Earth/moon system they placed the two spheres about 30 Earth diameters apart. Challenge them to think how far the Earth/moon system is from the sun, using the same scale. The answer can be calculated as follows:

Step 1. 93,000,000 miles distance between Sun and Earth

$$\frac{\text{93,000,000 miles distance between Sun and Earth}}{\text{8000 mile diameter for Earth}} = \text{11,625 (distance in diameters)}$$

Step 2 11,625 X 12.5 cm (diameter of model Earth) = 145,312.5 cm distance
Or, divided by 100,000 to = 1.45 km (rounded)

Materials: Meter stick, kite string & kite string roller, long field, playground or sidewalk, masking tape
Table 1: Planetary distance scale data (provided)
Table 2: Planetary moons scale data (provided)

Procedures:

1. Remind students what the term "average" means, and ask someone to describe what might happen in the way of assumptions when average planetary distances are used in activities like this (we get the impression that Neptune is closer to the sun than Pluto).
2. Have students complete the calculations first. Keys for these data tables are provided.
3. Students should complete the information on Tables 1 and 2 by dividing the distance and diameter values by a constant scale value. This could be done as an exercise for homework before the activity is begun.

EXAMPLE: using the scale 1 cm = 1,000,000 km and Mercury which is 58,000,000 km from the sun.

58,000,000 km/ 1,000,000 km per cm = 58 cm

The scale of 1 cm = 1,000,000 km provides a large scale model requiring nearly 60 meters of kite string to mark the distance between the sun and Pluto! A smaller scale model, by the order of one magnitude, may be made using the scale of 1 cm = 10,000,000 km. This will work better inside a classroom, but is not as dramatic when completed.

4. Divide your class into two teams that can take turns doing the activity. Each team needs nine planets, a sun, and 5 helpers/travelers.
5. Once you have a value for the scale distance from the sun to Pluto, begin measuring out enough kite string to stretch the distance plus about a meter extra. At a scale of 1 cm = 1,000,000 km, 60 meters of kite string will be needed. <u>You use only one piece of string for this activity.</u>

6. Cut ten pieces of masking tape about 20 cm each from the roll. Fold them in half, leaving a strip of tape about 10 cm in length with enough exposed tape at one end to wrap around the kite string. Students should make a line on the tape where it will wrap around the string and write one of the names of the nine planets or the sun on one of the pieces of tape.
7. Mark a distance about 0.5 meters from one end of the string and wrap a piece of masking tape around the string, and label it SUN.
8. Measure the scale distance to each planet (on the string) and wrap around the string the piece of masking tape labeled with the appropriate planet.
9. Use modeling clay or small balls to make spheres for each of the planets. You may wish to use the ping-pong balls on golf tees found in the kit. Place the spheres on the string model. You should make it clear to students that the planets would never line up in such a neat order in a straight line from the sun. Even if the planets were all in the same angular direction from the sun, their orbits are not in the same plane.
10. Once you have the model constructed, have students time a walk through the solar system with a digital watch. They may wish to work in pairs to time their walk and answer the following questions. Have students walk at a normal speed to time their journey!

i. Walk from the Earth to the Moon. How long did it take to travel? (It took the Apollo astronauts about three days to fly to the Moon.)

ii. Walk from the Earth to Mars. How long did the journey take? (It took the Viking spacecraft about one year)

iii. Walk from the Earth to Jupiter. How long did it take? (It took the Voyager spacecraft about two years.)

iv. Walk from the Sun to Pluto. How long did your journey take? (It takes light about 5.5 hours to do the trip!)

Extension: Have students calculate the distances to each of the planets from the sun if the Earth in the model was located 100 meters away (about 1 football field).

You may want to have students mark the orbital path of each of the planets by holding a separate string at the appropriate planet, and walking around the sun in a complete circle, marking their path with another long piece of string. If each planet has its orbit

marked, students can compare the orbital periods be each walking at approximately the same rate and watching one another.

The Ranger Rick **Astronomy Adventure** activity on "Intergalactic Invitation" (page 7 and 15) allows the children to think about Earth's position in the universe.

TABLE 1: AVERAGE PLANETARY DISTANCE AND DIAMETERS DATA

Object	Average distance from SUN (km)	Scaled Distance (cm)
SUN	-	
MERCURY	58,000,000	
VENUS	108,000,000	
EARTH	150,000,000	
MARS	228,000,000	
JUPITER	780,000,000	
SATURN	1,430,000,000	
URANUS	2,870,000,000	
NEPTUNE	4,500,000,000	
PLUTO	5,900,000,000	

KEY: AVERAGE PLANETARY DISTANCE AND DIAMETERS

Scale is 1 cm = 1,000,000 km

Object	Average distance from SUN (km)	Scaled Distance (cm)
SUN	-	
MERCURY	58,000,000	58
VENUS	108,000,000	108
EARTH	150,000,000	150
MARS	228,000,000	228
JUPITER	780,000,000	780
SATURN	1,430,000,000	1,430
URANUS	2,870,000,000	2,870
NEPTUNE	4,500,000,000	4,500
PLUTO	5,900,000,000	5,900

Scale is 1 cm = 10,000,000 km

Object	Average distance from SUN (km)	Scaled Distance (cm)
SUN	-	
MERCURY	58,000,000	5.8
VENUS	108,000,000	10.8
EARTH	150,000,000	15.0
MARS	228,000,000	22.8
JUPITER	780,000,000	78.0
SATURN	1,430,000,000	143
URANUS	2,870,000,000	287
NEPTUNE	4,500,000,000	450
PLUTO	5,900,000,000	590

WORKSHEET : PLANETARY DISTANCE & DIAMETERS

Scale is 1 cm = 1,000,000 km

Object	Average distance from SUN (km)	Scaled Distance (cm)
SUN	-	
MERCURY	58,000,000	
VENUS	108,000,000	
EARTH	150,000,000	
MARS	228,000,000	
JUPITER	780,000,000	
SATURN	1,430,000,000	
URANUS	2,870,000,000	
NEPTUNE	4,500,000,000	
PLUTO	5,900,000,000	

Scale is 1 cm = 10,000,000 km

Object	Average distance from SUN (km)	Scaled Distance (cm)
SUN	-	
MERCURY	58,000,000	
VENUS	108,000,000	
EARTH	150,000,000	
MARS	228,000,000	
JUPITER	780,000,000	
SATURN	1,430,000,000	
URANUS	2,870,000,000	
NEPTUNE	4,500,000,000	
PLUTO	5,900,000,000	

STARS

Is Anyone Out There?

Concept: We can estimate the probability of making contact with an intelligent civilization from another planet if we make some assumptions about the number of stars in the universe, the conditions under which intelligent civilizations will develop, and the probability that those conditions exist. An equation can be developed that permits students to relate their assumptions and to calculate the probability of extra-terrestrial (other worldly) life.

Difficulties: Mathematics threatens many students. The point of this activity is not to find a correct value, but to explore students' ideas about how the problem might be solved, to provide a model for the solution and to allow students to graphically demonstrate the resulting values of differing assumptions.

Relations: The time it takes for a message to reach us from another civilization depends upon the distance of that civilization. If the nearest civilization is 100 light years away, it will take 100 years for us to receive radio signals once they come into use as a means of communication. **Powers of ten** can be used to simplify and express the large numbers needed for these calculations. A key assumption in this activity is that significant numbers of stars survive long enough for intelligent civilizations to arise on planets around them, to discover radio communications, and to build a message for the stars.

Is anyone out there?

Description: Using assumptions and estimates made by astronomers, students will calculate the probability of the existence of intelligent life in our galaxy.

Materials: Student worksheets to guide their calculations.

Hook: Ask students to take out a piece of paper for a quiz. This should get an appropriate negative response! Have them put their names on the paper and ask them to answer only one question: "Do you believe there is intelligent life existing in our galaxy besides that found on planet Earth? Support your answer with two arguments."

Allow no more than five minutes for students to write their answers and then collect the papers.

Procedures:

1. Discussion is very important to the success of this activity! Ask for a show of hands of those who answered that intelligent life existed no where else but on Earth and ask for student volunteers to provide their arguments in support of their position. Now ask for volunteers to offer arguments in support of the existence of intelligent life elsewhere. You may wish to list the arguments from each side on the board. This portion of the activity could get very lively depending on students' arguments. Be sure to stay neutral, since the issue cannot yet be proven one way or the other, and students will have few tools for seeking solutions to the problem. You should encourage students to consider alternative viewpoints, and to provide as solid an argument for their position as possible.
2. Listen for the use of the word "probably" or "probability" and other words which connote uncertainty. After the discussion has gone on long enough for a fair sampling of the arguments to have been heard, talk to the students about the kind of language that they used. Point out to the students that when we (and scientists) do not really know for sure about something that our language tells that answers are uncertain. For example we use words like "probably, probability, maybe, hypothesis, guess, assumption, speculate, assume, or estimate" when we are unsure. Tell them that they will be using a way to find out about intelligent life in our galaxy using a formula that relies on assumptions and probabilities.
3. Ask for student volunteers to identify the types of information needed to make an educated guess about the probability of intelligent life existing elsewhere in our galaxy. This might be difficult for students to initiate, so your suggestions will be important. Allow students to consider the types of information and to explore the implications of their contributions. The information that needs to be collected and organized in order to solve this problem using the Drake equation is listed below.

   - The length of time it takes a civilization to develop radio communications.

   - The number of planets in our galaxy which can support life long enough to allow such a civilization to develop.

- Number of stars in our galaxy which will support life long enough for such a civilization to develop.

4. Tell the students that there is actually an equation used to look at the probability of other intelligent life in our galaxy. It is called the Drake equation. Much of the information needed to solve the problem is not known, and we must make some assumptions in order to proceed. The important assumptions which we must make concern the numbers of stars in the galaxy, the number of viable planets around the star which will sustain life, and the length of time it takes a civilization to develop radio communications. If we were to write an equation to calculate the odds, it might look like the following. See teacher's key and student worksheet.
5. Have students draw a representation of each step as they move through the calculations. Have them do it individually or make a class mural of the problem on butcher paper. For example, the picture would start with a picture of the Milky Way galaxy (a spiral galaxy) and would be labeled, 400 billion stars. Then, only one-half circled - 200 billion like our sun, and so on. Pictorial representation will assist students in understanding this equation.

THE DRAKE EQUATION

number of communicating civilizations in our galaxy now	=	number of stars in the galaxy	X	fraction of stars that last long enough for life to develop
	X	average number of planets per star	X	fraction of planets suitable to life
	X	fraction of those planets where life actually develops	X	fraction of planets with life where intelligent civilizations arise
	X	Lifetime of civilization with ability and desire to communicate	÷	lifetime of the galaxy

Some of these numbers are easier than others. For example, we think there are about 400 billion stars in our galaxy. Assuming that life develops on planets near stars like the sun, the stars should live at least 5 billion years. About half (0.5) of all stars do so.

The average number of planets is also unknown, except in our solar system where the number is known to be 9. To make calculations easy, we'll use 10 as the number.

The fraction of planets which are suitable for life is unknown. If we took our solar system as an example, it is 1 out of 9. Other astronomical considerations can be used to show that this fraction of stars with planetary systems that contain a planet suitable to life may be only 1 out of 4. If each planetary system had 10 planets, only 1 out of 40 planets (0.025) would be suitable for life.

The fraction of those planets where life actually develops also requires an assumption, since we only know of one to date. It may be between 0.5 and 1.0; if we use 0.5, we run the risk of underestimating the number of planets by half, a huge amount!

The fraction of planets with life where intelligent civilizations arise depends upon your definition of intelligence. If we set this number through knowledge of the only example we have (Earth), it is 1.0; let's be conservative and set it at 0.5, or one out of every two.

The lifetime of a civilization with ability and desire to communicate. Let's call this factor L. It is measured in years. We can and will manipulate this assumption to determine the final answer.

The lifetime of a galaxy is known from theory to be about 10 billion years.

Plugging the numbers above into the equation, we get the following result.

number of communicating civilizations in our galaxy now	=	400 billion	X	0.5
	X	10	X	0.025
	X	0.5	X	0.5
	X	L	÷	10 billion

When we multiply these all together, the answer is 1.25 L.

This equation, known as the Drake Equation, is used to consider only life within our galaxy because all other galaxies are too distant. Also, it

considers only communicating civilizations since they are the only ones with whom we could share information.

As you change the estimates for each value, the chances go up and down. The real unknown is L. If we define intelligence by the ability to send messages into space, our civilization has been doing so for about 100 years, since the invention of radio. (For the first few decades, the transmissions into space were accidental -- but we'll count them anyway.) However, the real question here is the lifetime of the civilization after the development of radio communications. There are many things that might cause a civilization to end -- nuclear war, disease, global warming, or impact by a comet. For example, if our civilization destroyed itself within 100 years of inventing radio communication, the answer becomes 125 civilizations within our galaxy.

Extensions: Your students may well wish to manipulate some of these assumptions to see the impact on the final estimate. A particular challenge might be to question the length of time a civilization could survive after it develops radio communications. If we assume our civilization will continue for another thousand years, the value for L becomes 1100, and the number of existing intelligent civilizations with which we could communicate goes up over 1000!

Resources from the materials kit:

Poster, "Galaxies"
Videotape "The Quest for Contact"

TEACHER'S KEY to WORKSHEET: USING THE DRAKE EQUATION

1. Our sun is only one of many stars in our galaxy. We estimate that the number of stars in our Milky Way galaxy is about 400 billion.	400 Billion X
2. It has taken 5 billion years to produce intelligent life on the planet Earth, so we will only consider stars that are at least as old as our star. Only about one-half are.	0.5 X
3. We do not know how many planets other stars might have but we do know that our system has 9 planets. The average number of planets per star is what we use in the equation next. Let's use 10 for this number to make our calculations easier.	10 X
4. Of these planets, about 1 planet, the Earth, in 10 (.10) has life, and scientists speculate that of all the planetary systems around, only 1 out of 4 (0.25) would even have a planet like Earth. So, to get the fraction of planets that are suitable for life, we multiply .10 X .25 to get the answer 0.025. Plug this into the equation.	0.025 X
5. Of these possible planets, we assume that life will actually develop on a some of them. We will say that the fraction of planets where life will actually develop is only one-half.	0.5 X
6. Next, we need to consider the fraction of the planets with life where intelligent civilizations arise. This will depend on our definition of "intelligence." Again we only are sure of one planet, the Earth. Using this knowledge, the fraction would be 1.0, but we will be conservative and say that only one out of two, or one-half, of planets suitable for life have intelligent civilizations.	0.5 X
7. The next value in the equation is called the L factor. This represents the lifetime of the civilization that has the desire and ability to communicate. This assumption will be manipulated to determine the final answer.	L =__________ divided by
8. From theory, we assume that the lifetime of the Milky Way galaxy is about 10 billion years. We now divide by this.	10 billion =
THE NUMBER OF COMMUNICATING CIVILIZATIONS IN OUR GALAXY NOW.	**1.25 L**

WORKSHEET: USING THE DRAKE EQUATION

1. Our sun is only one of many stars in our galaxy. We estimate that the number of stars in our Milky Way galaxy is about 400 billion. __________ X

2. It has taken 5 billion years to produce intelligent life on the planet Earth, so we will only consider stars that are at least as old as our star. Only about one-half are. __________ X

3. We do not know how many planets other stars might have but we do know that our system has 9 planets. The average number of planets per star is what we use in the equation next. Let's use 10 for this number to make our calculations easier. __________ X

4. Of these planets, about 1 planet, the Earth, in 10 (.10) has life, and scientists speculate that of all the planetary systems around, only 1 out of 4 (0.25) would even have a planet like Earth. So, to get the fraction of planets that are suitable for life, we multiply .10 X .25 to get the answer 0.025. Plug this into the equation. __________ X

5. Of these possible planets, we assume that life will actually develop on a some of them. We will say that the fraction of planets where life will actually develop is only one-half. __________ X

6. Next, we need to consider the fraction of the planets with life where intelligent civilizations arise. This will depend on our definition of "intelligence." Again we only are sure of one planet, the Earth. Using this knowledge, the fraction would be 1.0, but we will be conservative and say that only one out of two, or one-half, of planets suitable for life have intelligent civilizations. __________ X

7. The next value in the equation is called the L factor. This represents the lifetime of the civilization that has the desire and ability to communicate. This assumption will be manipulated to determine the final answer. L = __________

divided by

8. From theory, we assume that the lifetime of the Milky Way galaxy is about 10 billion years. We now divide by this. __________ =

THE NUMBER OF COMMUNICATING CIVILIZATIONS IN OUR GALAXY NOW. __________

MOTIONS
Speed of Light

Concept: Light travels at a constant speed of 300,000 km/second, or 3.0 x 10^5 km/second. Nothing can go faster than this speed. The speed of light is a common measure of interstellar distances, since it is used to represent the length of time it would take light to travel from any stellar light source to any receiver.

Difficulty: The speed of light is usually expressed in distance per second. Stellar distances are commonly expressed in light-years. A light year is the distance light would travel in one year. Students may have difficulty calculating this distance, or confuse it with units of time. Help them think through the problem and seriously consider their answers. Encourage them to use calculators if possible to solve the problem.

Relations: The distances between the sun and the planets are often described in AU's, Astronomical Units. 1 AU is equal to the distance from the sun to the Earth. This distance in light time is a little over 8 minutes. The activities presented in the section **Planetary Scales** can also be calculated in light time. Large numbers are best expressed with the **powers of ten.**

Light time

Preparation: Calculators may make this activity more effective.

Description: Students will convert distances in kilometers to distances in light time. They will set up a chart to measure the distances between the Earth and the other planets, and between the sun and the other planets.

Hook: Announce the following news flash:

> The sun has just exploded!! How long will it take for the flash from the explosion to reach the Earth if it is traveling at the speed of light?

Materials: Student worksheets, pencils with erasers

Procedures: 1. Work the problem that you gave them in the hook. Talk them through the steps. They will then calculate the other distances in light time using these same steps.

$$\text{Flash of light time from the sun to Earth} = \frac{\text{distance}}{\text{C (speed of light)}} = \frac{150{,}000{,}000 \text{ km}}{300{,}000 \text{ km/sec}}$$

$$= 500 \text{ sec} \quad \text{convert to minutes} \quad 500 \text{ sec} \times \frac{1 \text{ minute}}{60 \text{ sec}} = \underline{8.3 \text{ minutes}}$$

2. Hand out student worksheets. Students will be required to do many calculations and may also need calculators or scratch paper for hand calculations.
3. Using the data given in the worksheet, have students calculate how long it would take for light to reach each of the planets from the sun. Note that for this exercise you can assume they are in a straight line, going away from the sun. See teacher's key for the answers.
4. After calculating the values for each planet, have students calculate the time it would take the reflected light coming from each of the planets to reach the Earth. This calculation requires some thought, although the mathematics is no more complex than simple subtraction problems. See if students can figure out how to determine it on their own.
5. You may have students compare these light distances to the light time it takes to get to our nearest neighbor star. The nearest star beyond the sun is Proxima Centauri (also known as Alpha Centauri). It is 4.2 light years away. How long would it take, traveling at the speed of light, to get there? Using this information, how far away is Proxima Centauri in kilometers?

Extension: You might encourage students to imagine the communication difficulties which might arise during a conversation to a distance planet. You might also challenge them to explain how it could be that on the Starship Enterprise the crew is able to communicate with other ships in space even though they assert they are traveling faster than the speed of light, at "WARP" speed? Such communication is not possible at the present time, and may never be possible without major changes in our thinking about the way light and space behave.

Resources from the materials kit:

Poster, "The Solar System"
Poster, "Galaxies"

Teacher's Key: Travel time at light speed

Celestial Body	Average distance from Sun (km)	Travel time for light from the Sun	Travel time for light from the body to reach Earth
Sun		0 minutes	8.3 minutes
Mercury	58,000,000	3.2 minutes	5.1 minutes
Venus	108,000,000	6.0 min	2.3 min
Earth	150,000,000	8.3 min	0 min
Mars	228,000,000	12.7 min	4.4 min
Jupiter	780,000,000	43.3 min	35.0 min
Saturn	1,430,000,000	1 hr 19 min	1 hr 11 min
Uranus	2,870,000,000	2 hr 39.4 min	2 hr 31.1
Neptune	4,500,000,000	4 hr 10 min	4 hr 1.7 min
Pluto	5,900,000,000	5 hr 27.8 min	5 hr 19.5 min

*Note: These "travel times" are only true if the planets are all lined up!

Worksheet: Light Time

Sample calculation:

$$\text{Light time from the sun to Earth} = \frac{\text{distance}}{\text{C (speed of light)}} = \frac{150{,}000{,}000 \text{ km}}{300{,}000 \text{ km/sec}}$$

$$= 500 \text{ sec} \quad \text{convert to minutes} \quad 500 \text{ sec} \times \frac{1 \text{ minute}}{60 \text{ sec}} = \underline{8.3 \text{ minutes}}$$

Travel time at light speed

Celestial Body	Average distance from Sun (km)	Travel time for light from the Sun	Travel time for light from the body to reach Earth
Sun		0 minutes	8.3 minutes
Mercury	58,000,000	_______	_______
Venus	108,000,000	_______	_______
Earth	150,000,000	8.3 min	_______
Mars	228,000,000	_______	_______
Jupiter	780,000,000	_______	_______
Saturn	1,430,000,000	_______	_______
Uranus	2,870,000,000	_______	_______
Neptune	4,500,000,000	_______	_______
Pluto	5,900,000,000	_______	_______

SPECIAL INTEREST

Lunar Mining

Concept: The resources that become available through the technology of space travel may play a major role in determining who will be world leaders in the next century. Who and how these resources are made available is an issue that will be hotly debated as soon as the economic feasibility of resource exploitation is demonstrated. Many decisions which must be made about space exploration are not technological decisions, but human ones. Access to space technology and sharing the resources of the moon and nearby planets are unresolved issues. The students of today and their children may be making important decisions about how we utilize the resources of space.

Difficulties: Role playing may be difficult for students who haven't tried it, but there are issues here that are unfamiliar to students. Allow time for student groups to clarify the goals for their group, and then to meet in the larger group to discuss the issues. Once students have set objectives for themselves in activities like this, they often bring powerful ownership to the success of their point of view. Students should be reminded of the game nature of the exercise and to strive to see other points of view.

Relations: The moon is the featured concept in **Phases and Perspectives**. The debate over resources becomes more important if in fact the answer to the question **Is Anyone Out There?** suddenly becomes "Yes" through contact with another civilization. The feasibility of resource management given the difficulties of distance and scale can be related to the difficulties of scale encountered during the European colonial period.

Lunar mining

Preparation: Make copies of Role Cards, negotiation sheets and country cards as described in **Astronomy Adventures** book.

Description: Students will role play as representatives of imaginary countries negotiating mining rights and access to lunar resources.

Materials: Pages 67-68 of Ranger Rick's Naturescope Astronomy Adventures, Copy cat pages (pp. 71-72), Role Cards (one for each

student), negotiation sheets for each group, a copy of the country cards for each group so that they can know about the other countries, large sheet of easel or butcher paper for each group.

Procedures:
1. Carry out the activity as described in the **Astronomy Adventures** book.
2. Students should be divided into five "national" teams for this activity, and they could nominate and elect representatives to the proposal meeting to argue their "national" position.
3. As suggested, the meeting and adoption of a specific proposal should be followed by a discussion with students about the problems and issues raised by the activity.

Extension: Have students role-play a United Nations' type of meeting at which delegates from all the countries decide on laws governing space exploration and the sharing of resources found anywhere in space.

Get students to research what actual resources the moon has to offer us Earthlings.

Resources from the materials kit:

Official Rand McNally Map of the Moon

INSTRUMENTS
Powers of Ten

Concept: Scientists use "scientific notation" to express very large and very small numbers. The known universe can be described mathematically as having a range of 10^{41}. It ranges from the smallest measure, 10^{-16} meters, to the largest, 10^{25} meters. Using the powers of 10 allows us to efficiently relate and manipulate large magnitudes of matter, energy and distances.

Difficulty: The operations of exponential numbers is not simple, and students may not understand how the power of ten allows them to compare galaxies and atoms. The purpose of the activity is not to teach complex mathematics, but to enable students to realize that the measurements of all objects in the universe are possible and can be related to each other, and to understand roughly how the human scale is given a continuum from smallest to largest.

Relations: Mathematics is the heart of the sciences, as can be seen in many of the activities in this unit and others. The use of scientific notation enables scientists to work with galactic and **planetary scales**, to calculate the **speed of light**, to predict the possibilities of black holes and to explore the answer to the question **Is anyone out there?**

Powers of 10

Preparation: Have several students use pieces of masking tape to divide a 100' rope or the string into 44 equal sections.

Description: Using the range of 41 magnitudes, students will create a logarithmic scale model of the nearby universe, and locate the appropriate magnitudes for specific structures.

Hook: Watch the film "Powers of Ten." Measure items in your classroom or school that are powers of 10 greater or smaller than the doorway in your classroom, e.g. 100 times larger, 10 times larger, the same size, 10 times smaller, 100 times smaller, 1000 times smaller...

Materials: String (provided) measured into 44 equal segments, laminated cards with powers of 10 (provided), and student drawings to be attached to the string. Powers of ten videotape (provided).

Procedures:
1. Hang the string across the classroom low enough that dangling pictures can be tied on along it. It can be raised later so that it does not present a temptation or interfere with normal movements around the room.
2. Have students tie each "Powers of 10" card to one of the marks on the string.
3. Now have students work in small teams to prepare drawings of things that might measure that number of meters. Examples for many are given in the videotape. You may want to allow the students to watch the video several times so that they can figure out what to draw.
4. Have students discuss where each of the drawings should be placed on the string and have them place them there.

Extension: Students may wish to place cards which indicate the various nomenclature for the different powers of ten. The following list includes some of the possible cards you could include.

1 fermi	10^{-15} meters
1 angstrom	10^{-10} meters
1 nanometer	10^{-9} meters
1 micron, Micrometer	10^{-6} meters
1 millimeter	10^{-3} meters
1 centimeter	10^{-2} meters
1 meter	10^{0} meters
1 kilometer	10^{3} meters
1 astronomical unit	10^{11} meters
1 light year	10^{16} meters
1 megaparsec	10^{22} meters

Watch Powers of 10 once again. Have students choose a different "Powers of 10" point of view and write about what the rest of the universe looks like from their perspective.

Resources from the materials kit:

Poster, "The Solar System"
Poster, "Galaxies"
Poster, "Horsehead Nebula in Orion"
Videotape, The Films of Charles & Ray Eames Vol. I, The Powers of Ten

BIBLIOGRAPHY

Branley, F.M. (1986). What makes day and night? New York: Harper Children's Books.

Branley, F.M. (1961). A book of planet Earth for you. New York: Crowell.

Braus, J. (Ed.). (1992). Ranger Rick's nature scope astronomy adventures. Washington, DC: National Wildlife Federation.

Comets: Time capsules of the solar system. Burbank, CA: Walt Disney Educational Films.

Eames, C. & R. (1989). Volume I/powers of ten (video). Santa Monica, CA: Pyramid Film.

Goldsmith, D. & Owen, T. (1992). The search for life in the universe. New York: Addison-Wesley.

Jobb, J. (1977). The night sky book. New York: Little.

Krupp, E.C. (1991). Beyond the blue horizon: Myths and legends of the sun, moon, stars and planets. New York: Harper Collins.

Krupp, E.C. (1989). The big dipper and you. New York: William Morrow.

Lurie, A. (1979). The heavenly zoo: Legends and tales of the stars. New York: Farrar, Straus and Giroux.

Moroney, L. (1988). Feather moon: American Indian star tales (cassette recording). Oklahoma City: Author.

Moroney, L. (1991). Tales of the sun and moon (cassette recording). Oklahoma City: Author.

Rey, H.A. (1973). The stars: A new way to see them. Boston: Houghton Mifflin.

Simon, S. (1977). Look to the night sky. New York: Viking Press.

Sneider, C.I., Gould, A., and Hawthorne, C. (Eds.). (1989). LHS GEMS: Color analyzers. Berkeley: Lawrence Hall of Science, University of California.

Sneider, C.I. (Ed.). (1986). LHS GEMS: Earth, moon, and stars. Berkeley: Lawrence Hall of Science, University of California.

Sneider, C.I. & Gould, A. (Eds.). (1988). LHS GEMS: More than magnifiers. Berkeley: Lawrence Hall of Science, University of California.

Vautier, G. The shining stars (Greek legends of the zodiac).

Vautier, G. The way of the stars (Greek legends of the constellations).

Astronomy Kit Materials Listing

Unit label	Unit	LE	Activity	Description	Quantity	Source
A	Earth and Stars	Models	Building Constellation Viewers	Aluminum foil, roll, regular, 12"*	1	G
C	Stars and Gravity	Debris	Collecting rocks from space	Aluminum pie pans	16	G
A	Earth and Stars	Stories in the stars	Stories on Tape	Audio cassette tape, "Feather Moon: American Indian Star Tales" set	1	Astronomical Society (415) 337-2624
D	Scales and Measures	Phases & Perspectives	Earth/Moon Model	Balls, 1.25" diameter (styro)	1	C
D	Scales and Measures	Phases & Perspectives	Earth/Moon Model	Balls, 5" diameter (styro)	1	C
D	Scales and Measures	Phases & Perspectives	Lunar phases	Balls, ping-pong on golf tees	24	G
A	Earth and Stars	The Sun	How Big is the Sun?	Batteries for flashlights* (D cell)	4	H or G
A	Earth and Stars	Spin/Rotation	How old are you?	Book, "Astronomy Adventure", Nature Scope	1	National Wildlife Federation (800) 432-6564
D	Scales and Measures	Lunar Mining	Mining on the moon	Book, "Astronomy Adventure", Nature Scope	1	National Wildlife Federation (800) 432-6564

H= hardware
G= grocer or gen
S= Kit supplier
Sci= Sci supplier

W= wholesale, like white swan
C= craft, like Michael's
Toy= Toy store

Astronomy Kit Materials Listing

Unit label	Unit	LE	Activity	Description	Quantity	Source
C	Stars and Gravity	Colors & spectra	Color analyzers	Book, "Color analyzers," GEMS,	1	GEMS (512) 642-7771
B	Spheres and Orbits	The spherical earth	Ancient models of the earth	Book, Earth, Moon, and Stars from GEMS,	1	GEMS (510) 642-7771
S				Book, GEMS Teacher Handbook	1	GEMS (510) 642-7771
B	Spheres and Orbits	Telescopes	Telescopes	Book,"More than Magnifiers,"	1	GEMS (510) 642-7771
S				Book, <u>The Big Dipper and You</u>	1	Krupp, E.C. Morrow Jr. Books, 105 Madison Ave NY 10016
B	Spheres and Orbits	The spherical earth	Evidence for a sphere	Cardboard disk, 8" diameter (approx.)	2	C
C	Stars and Gravity	Colors & spectra	Light codes	Cards, color analyzers, set	1	GEMS (510) 642-7771
D	Scales and Measures	Powers of 10	Powers of 10	Cards, Powers of 10, set	1	S
B	Spheres and Orbits	Orbits/Revolution	What's your sign?	Cards, Zodiac, set of 12	1	S

139

140

H= hardware
G= grocer or gen
S= Kit supplier
Sci= Sci supplier

W= wholesale, like white swan
C= craft, like Michael's
Toy= Toy store

Astronomy Kit Materials Listing

Unit label	Unit	LE	Activity	Description	Quantity	Source
A	Earth and Stars	Spin/Rotation	Sun Shadows	Chalk, colored *, box	2	C
B	Spheres and Orbits	Modeling Constellations	Table Top Constellations	Clay, permaplast, stick*	1	C
A	Earth and Stars	Models	Building Constellation Viewers	Copy Cat page "What's Your Sign"?	1	S
B	Spheres and Orbits	Modeling Constellations	Table Top Constellations	Flashlight, household	1	G
D	Scales and Measures	Phases & Perspectives	Lunar phases	Golf tees (for ping pong balls)	24	G
B	Spheres and Orbits	Telescopes	Telescopes	Lenses, double convex (longer focal length)	10	GEMS (510) 642-7771
B	Spheres and Orbits	Telescopes	Telescopes	Lenses, double convex, (shorter focal length)	10	GEMS (510) 642-7771
C	Stars and Gravity	Colors & spectra	Colors in light	Light bulb (60-100 watts)	1	G
B	Spheres and Orbits	Telescopes	Telescopes	Lightbulb, red	1	G

141

142

H= hardware
G= grocer or gen
S= Kit supplier
Sci= Sci supplier

W= wholesale, like white swan
C= craft, like Michael's
Toy= Toy store

Astronomy Kit Materials Listing

Unit label	Unit	LE	Activity	Description	Quantity	Source
C	Stars and Gravity	Debris	Collecting rocks from space	Magnet, any type	1	C
C	Stars and Gravity	Debris	Collecting space rocks	Magnifiers	1	C
C				Microscope slides	1	S
C	Stars and Gravity	Debris	Collecting space rocks	Needle, large or nails	6	G
S				Official Rand McNally Map of the Moon	1	Astronomical Society (415) 337-2624
		Use as needed		Poster, "Comets"	1	Astronomical Society (415) 337-2624
S	Stars and Gravity	Galaxies	What is a year	Poster, "Galaxies"	1	Astronomical Society (415) 337-2624
S		Use as needed		Poster, "Horsehead Nebula in Orion"	1	Astronomical Society (415) 337-2624
S	Spheres and Orbits	Planets and Moons	Cosmic Vacation	Poster, "Jupiter with Four Moons"	1	Astronomical Society (415) 337-2624

143

144

H= hardware
G= grocer or gen
S= Kit supplier
Sci= Sci supplier

W= wholesale, like white swan
C= craft, like Michael's
Toy= Toy store

Materials kit resource list

Astronomy Kit Materials Listing

Unit label	Unit	LE	Activity	Description	Quantity	Source
		Use as needed		Poster, "Meteorites"	1	Astronomical Society (415) 337-2624
S	Spheres and Orbits	Planets and Moons	Cosmic Vacation	Poster, "Saturn with Six Moons"	1	Astronomical Society (415) 337-2624
S		Use as needed		Poster, "The Full Earth"	1	Astronomical Society (415) 337-2624
		Use as needed		Poster, "The Solar System"	1	Astronomical Society (415) 337-2624
B	Spheres and Orbits	Modeling Constellations	Table Top Constellations	Rods, wire: #1-22.6 cm: #2-19 cm: #3-18 cm; #4-16.6 cm; #5-15 cm; #6-14 cm; #7-16 cm	7	H
D	Scales and Measures	Planetary Scales	Planetary scales	Roller with kite string	1	G/Toy
A	Earth and Stars	Stories in the stars	Stories on tape	"Sky Challenger" Star wheels, set,	1	GEMS Eureka Program (510) 642-1016
C	Stars and Gravity	Debris	The Comet Game	String, ball *	1	G
B	Spheres and Orbits	Modeling Constellations	Table Top Constellations	Template for table top constellation	1	S

H= hardware
G= grocer or gen
S= Kit supplier
Sci= Sci supplier

W= wholesale, like white swan
C= craft, like Michael's
Toy= Toy store

Astronomy Kit Materials Listing

Unit label	Unit	LE	Activity	Description	Quantity	Source
A	Earth and Stars	Constellations	Star Patterns	Transparencies, 3 showing Leo: Dots, Lines, Lion	1	S
S				Videotape, The Films of Charles & Ray Earnes Vol. I, The Powers of Ten	1	Astronomical Society (415) 337-2624
C	Stars and Gravity	Debris	Collecting space rocks	Ziploc bag, qt. size	1	G

147

148

H= hardware
G= grocer or gen
S= Kit supplier
Sci= Sci supplier

W= wholesale, like white swan
C= craft, like Michael's
Toy= Toy store

NOTICE

REPRODUCTION BASIS

- [x] This document is covered by a signed "Reproduction Release (Blanket)" form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

- [ ] This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").